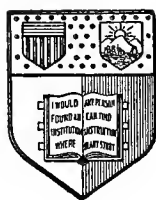


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MINOR THESIS
Irrigation With Reference To Truck Farming

CHARLES W. HUNT



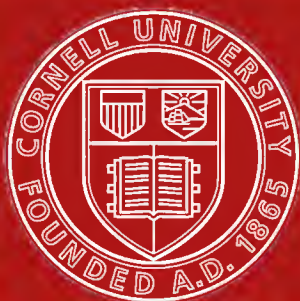
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IRRIGATION WITH REFERENCE TO
TRUCK FARMING IN THE EASTERN UNITED STATES.

Minor Thesis.

Presented for the degree M. S. A.

1911.

By

C. S. Wright.

Irrigation with Reference to Truck Farming in the Eastern United
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I R R I G A T I O N .

Supplying vegetation with moisture when natural causes are not sufficient to produce the results desired. Mechanical interference with nature for definite results.¹

Two purposes of irrigation.²

To increase the crop producing power of land that is cultivated under rainfall moisture.

To bring into cultivation lands that receive too little rainfall for the profitable production of crops.

Objects of Irrigation.

The chief use of irrigation is to supplement an irregular and insufficient rainfall. The secondary objects are to enrich the land or to correct alkali.³

To enrich the land:

Many waters, although they may seem perfectly pure, carry some fertilizing material in solution or suspension which will be deposited in the soil when the water is applied and allowed to evaporate or seep down. Sewage waters are possibly extreme cases of water carrying fertility.

Water from a muddy stream may be applied to an open sandy soil to change its texture, bringing its particles in closer contact with each other.

1. N. H. Bul. 34.

2. Bailey, Cyc. Agr., Vol. IV, p, 154.

3.S. W. Fletcher, Soils, 236-237.

1. PRINCIPLES OF IRRIGATION.

Relation of soil moisture to plant growth.¹

It is probable that the earliest forms of life came into being in the water, and were made very largely of water. As yet there is no form of plant known to exist without water although there are some which can live on a very small supply.

Water makes up a large part by weight of all living and growing parts of plant life, and it is a medium in which the transformation of the crude materials to assimilable food-products takes place, also furnishing a means of transportation of these products to the points of growth.

There are conditions where plants appear to thrive and produce fair yields with relatively small amounts of water, but there is always a supply somewhere either from seepage or capillarity which the plant's roots reach.

Water is indispensable to plant growth and is used more than any other substance, so that it is impossible to overestimate its importance as a plant food, although it must be borne in mind that water is seldom if ever a complete plant food.

Frequent warm rains in springs are of greater importance to a hay meadow than is an application of

1. King, pp. 1-45.

fertilizer without rain.

On a potato field at the time the tubers are forming, an abundance of water is far more important than an abundance of fertilizer.

All waters which have been exposed to the atmosphere have become charged with oxygen, carbonic acid and nitrogen, which they carry with them into the soil, and these aid in one way or another, both the physical and life processes which make for fertility.

Experiments with wheat at Tulare showed the maximum yield to be produced when from 18-24 inches of water was applied. Barley showed best yield with same amounts. Horse beans at Berkeley; maximum amount used was 38". Yield increased with the increase of application.

The crop-producing capacity² of a certain amount of rain-fall or irrigation depends upon several factors such as, time of irrigation or time when rain falls, retentiveness of the soil, and skill of the farmer in the conservation of moisture. Ten inches of rain-fall in one section may be equal to sixteen inches in another.

At least eight to twelve inches of rain-fall are needed to produce a profitable crop of wheat, although the wheat uses less than half that much. It is estimated that 4 1/2 inches of rain-fall is required to produce a yield of 15 bushels of wheat, and twice as much or nine inches to produce 30 bushels.

1. O. E. S. Bul. 177, p. 64.
2. Fletcher, Soils, p, 238.

2. RELATION OF IRRIGATION TO RAIN-FALL AND CLIMATE.

The¹ question of whether irrigation should be practiced in any given station, and will it be profitable, may be answered directly by the amount and seasonal distribution of rain-fall, coupled with the soil and climate

In sections where the annual rain-fall is very small, irrigation is a necessity, while in sections where there is a high annual rainfall, but not always well distributed throughout the growing season, irrigation is used as a supplement.

In California the rain all falls during the rainy season, which is from November to April. In Washington the rainy season is from October to May.

In both of these cases the water gets well into the soil before the crop is put upon the ground. There is moisture enough present to produce germination. The roots at first develop near the surface, then as the moisture is reduced, the roots increase in depth, advancing more and more deeply as the season progresses, and the water-table becomes lowered.

In these two sections the rain falls in the cooler portion of the year, when the air is more nearly saturated and the wind velocities are small, the sun being obscured much of the time by clouds; these conditions allow the greater portion of the water to enter the soil,

1. King, 95-110.

the loss from evaporation being small. The soil is deep, and retentive, preventing loss from drainage and acting as a very capable reservoir, thus by the aid of good surface cultivation holding the moisture, giving it up slowly to the plant roots and keeping them quite well supplied during their growing season.

In Kansas where the rain falls largely in the form of showers in the heated, sunny season of the year, when wind velocities are high and the air extremely dry, a large portion of the ran is lost by evaporation, only the surface soil is moistened, the plant roots develop in the surface few inches and when a short drought occurs the roots tend to go down for moisture, but there is none there and they are destroyed, so that when the next shower comes there are no rootlets to absorb it, and it is all lost to evaporation.

3. WATER STORAGE CAPACITY TO DIFFERENT SOILS.

In Hawaii¹ experiments were carried on to determine the power of soils to absorb and retain moisture, the results showing that soil containing nitrogen in the form of decayed vegetable matter increased the absorbing power from 44.6% to 66.5%, and the retaining power from 6.2% to 19.7%.

Following the action of organic matter, the next most important factor in determining the power of soils to take up and hold water is the relative amount of clay, or of the elements which form clay, present in the soil.

Soil samples without clay:--

Water absorbed 31.8%, at the end of one month there was left 12.4%, and at the end of five months 2.5%.

Water absorbed 86.4%, end of one month 52.2%, end of five months 28.2%.

Illustrating the material increase in absorption and retention power, when clay was added.

In Colorado² from 1870-1875 there was no plant adapted to upland culture. Alfalfa arrived in 1873, and up to this time the potato crop was not benefited by irrigation in the Greeley colony.

When alfalfa began to be turned under as a green crop, thus adding humus to the soil, they found it was pos-

1. Off. Expt. Stas. Bul. 90.
2. Yearbook, 1904, pp. 311-322.

Promoting storage of moisture in soils.

Where the annual precipitation is only barely sufficient for the crop, it is very important that the soil be kept in such a condition that it will be able to take up and store as large a proportion of it as possible. Thus it is evident that ploughing should be done in the fall as early as possible and deep enough to afford a reservoir to receive the rain-fall which may fall before spring.

4. DISTINCTION BETWEEN IRRIGATION IN ARID AND HUMID CLIMATES.

In the arid climates the soil is light and sandy, the rain-fall is very small, evaporation is great, in all the conditions are much against the remaining of any moisture in the soil. The soil is rich in the chemical elements of fertility and is fertile, the rain-fall is insufficient to sustain crop production.

Artificial application of water is necessary to mature any crop.

Experiments seem to show that the best results are obtained by giving the land thorough soakings at considerable intervals of time, practicing deep surface tillage and thus encouraging deep root development to avoid the burning hot rays from the sun.

The scorching winds of the arid sections are a menace to plant growth, drying the water from the soil and from the plants as well. Thorough irrigation and surface tillage is the only means by which plant growth may be secured.

Other¹ things being equal, more water will be required in an arid region than in a humid region; more in a warm than in a cold climate; more on a clay than on a sandy soil; more in a windy section than in a region of a comparatively still atmosphere; more with a high soil moisture content, more on a poor soil and more water is used per pound of dry matter produced in a small crop than is required in a large crop.

¹ ~~Lyon~~ & Fippin, Soils, p. 134.

In humid climates the annual rain-fall is sufficient to mature crops, the question of distribution being the important one. There may be a time during the growing season when a drought will result from the lack of rain; in such cases irrigation is necessary to supplement for rain.

On light sandy soils heavy irrigations are perfectly safe, but on heavy clay soils judgment must be used in the amount of water to apply at one time. It is not uncommon to get sudden heavy showers of an inch or more followed perhaps by a day or more of stormy weather; if this comes just after a thorough

irrigation has been made, there is a possibility of decrease rather than increase in crop production, as excessive moisture during a time when the air is also heavily laden is very conducive to spore germination and thus to disease spread. This applies more especially to the more valuable crops such as truck garden or (vegetable) crop.

II. EXTENT OF IRRIGATION.

Historical Development of Irrigation in the Old World.

It is stated that the first artificial lake or reservoir of which we have authentic record was lake Maeris, constructed some historians say by King Maeris, and others by King Amenemhet III, 2084 B. C. This lake communicated with the Nile by a canal 12 miles long and 50 feet broad. When the reiver rose to a height of 24 feet and was likely to be disastrous to crops, the sluices were opened and the river relieved by sending the flood into the lake, and at the time of low water the gates were opened and the water from the lake used to reinforce the stream. In 1491 B. C., Swostris, who reigned in Egypt, is said to have had a great number of canals cut for the purposes of trade and irrigation. Irrigation canals in Egypt was very numerous, using up the greater part of the flow from the Nile.

The Assyrians appear to have had great skill in irrigating and water problems in very early times, they developed extended irrigating systems, which converted the naturally sterile valleys of the Euphrates and Tigris into the most fertile of fields. They constructed a reservoir 42 miles in circumference and 35 feet deep into which they could turn the whole Euphrates river, by means of an artificial canal. One of their great works which stands out as a piece of bold engineering hardly equalled by anything of its kind in modern times, is the great canal from the Tigris leading toward Samara, which was 400 miles long with a width varying from 250 to 400 feet, and used with its numerous branches on either side to the broad irrigated fields, and its main part used for commerce.

At the time of the invasion of Agrica the Syracusan General wrote that the African shore was covered with gardens and large plantations everywhere abounding in canals by means of which they were plentifully watered.

In the early Grecian and Roman history irrigation and waterways are spoken of, and the descriptions show that they must have been immense and required an immense amount of time and labor to construct. Rome in Nero's time was supplied with water by large aqueducts for drinking purposes, etc., said to aggregate a length of 255 miles, and deliver 312,500,000 gallons,

When the Romans invaded France they constructed great systems of water works for the cities in the various places. The Nismes conduit constructed 19 B. C., and delivering 14,000,000 gallons daily, is noted for the great Pont du Gard which carried it across a ravine and which is

spoken of as one of the greatest monuments the Romans left in France.

China, like Egypt, dates its early enterprises of irrigation and transportation by water far back into antiquity; the great Imperial Canal there has a length of 650 miles, connecting the Hoany-Ho with the Yang-tse-Kiang. Its depth seldom exceeds 5 to 6 feet and the water in it moves at about 2 1/2 miles per hour.

Third edition, King, 66-71.

The¹ earliest Egyptian sculptures show water being raised from the Nile in buckets and poured on the land. The works along the Nile and the Euphrates have an unbroken historical record reaching back more than 2000 years before Christ. The great works of Beloochistan

were built by a race whose history is unknown. There are irrigation works in Southern India built by the Hīndus which antedate the Christian era, while in many parts of the Western Hemisphere, notably in Peru and the southwestern part of United States, there are remains of ancient irrigation works, evidently centuries older than any historical record. In some countries, irrigation has risen and disappeared with the civilization of which it formed a part. This is true of the irrigation works connected with the Aztec Civilization in the Western Hemisphere. There are evidences of prehistoric irrigation in the Hawaiian Islands. Many of the irrigation canals of the Tigris and Euphrates have been abandoned, and few have maintained their ancient importance.

1. Bailey, Cyc. Agr. p. 420.

Irrigation has been practiced in America from time immemorial by the town-building Pueblo Indian tribes inhabiting portions of New Mexico and Arizona. The Mormons entered Salt Lake Valley 1847, at which time there were probably not more than a few hundred acres irrigated by Indians, Mexicans and the California Missions. The Union colony settled at Greeley, Colo., in 1870, 23 years after the Mormons had begun to irrigate. It is probable that there were not more than 20,000 acres under irrigation in the United States in 1870. From 1870 to 1880 was a period of rapid development of small ditches constructed by individuals and associations of farmers. At the end of that period there were probably 1,000,000 acres under irrigation. From 1880 to 1890 occurred the "boom" of speculative enterprise of money and labor, nearly all proving financial failures, but they aided in the extension of irrigation.

In 1889 there were 3,631,381 acres irrigated on 54,136 farms, average area of 67 acres. The following decade, irrigated acreage doubled in extent.

The agricultural wealth of that vast region lying west of the Missouri River was first made known by settlers whose poverty compelled them to make use of the cheapest methods in rendering the arid lands productive. They lead water from the nearest stream by the

use of plough and shovel. Since then many implements and methods have been used but still much remains to be done before the water of the western streams is efficiently and economically applied to arid lands. To remedy this the Irrigation investigations of the Department of Agriculture were instituted (1896) to be carried on wherever practicable in conjunction with western experiment stations. Results: 1. To show that vast amounts ^{are} of water/now being wasted in transportation, delivery, and use by crude and defective means. This waste is being slowly diminished but still the highest duty has not been reached.

Land now irrigated in the West 13,000,000 acres. Over 50,000,000 acre feet of water being diverted for this purpose, and it is believed that only about one-third of this volume of water is utilized in nourishing plant growth, balance being wasted. All of this waste cannot be prevented, but it is thought that enough might be saved to irrigate under careful use about 7,000,000 acres.

Census XII, Vol. 6, p. 801.

EARLY DEVELOPMENT OF THE CULTIVATION OF LAND
BY IRRIGATION IN THE NEW WORLD.

Traces of an early civilization in Colorado, New Mexico and Arizona, extending through Mexico and Central America into Peru, are found in the ruins of ancient towns and irrigating canals in many places. When the Spaniards invaded Mexico, Central America and Peru, they were greatly surprised to find in these countries, particularly in Peru, the land of the Incas, very elaborate and extensive irrigation systems, laid out and in actual general use by these people.

Prescott, in his "Conquest of Peru," speaking of the use of water for irrigation, writes that water "was conveyed through canals and aqueducts built on a noble scale from large slabs of Freestone fitted together without cement, and carrying water great distances in some cases. One that traversed the district of Condesuyos was between 400 and 500 miles long. They lead from some natural reservoir in the heart of the mountains, being fed at intervals from other basins. These were built without the aid of iron tools, through ores and around all sorts of difficult lands.

King, 71-72.

IRRIGATION FROM PLINY'S NATURAL HISTORY.

During the first century and before water was used to help trees during the heats of summer, and was known to be a benefit. Also it was known that water was injurious in winter, its effects in autumn depended upon the nature of the soil. It was known that an excess injured the roots, and that old trees required more than young. In the Fabian district of Italy, the habit of irrigating the fields or vineyards, the water took the place of the weeding hook as it killed all weeds, and nourished the corn, showing the water must have been salt. In winter when frosts prevailed, they irrigated to warm the soil, the water from the Sangro River having this peculiar effect.

THE PROPER METHOD OF WATERING GARDENS. Theophrastus.

Evening is preferred to morning, evaporation not being so quick, and the plant profiting more from the water.

Pliny.

The proper times for watering are the morning and the evening. Transplanted plants especially benefited.

The¹ first conception of irrigation as essential to the growth of fruits in a country with a rainless summer.

The Spanish missionaries who entered California from Mexico in 1769 established fruit gardens and vineyards with irrigation facilities along the coast region.

They laid off their plantations in old Spanish style and proceeded upon the assumption that fruit could not be grown in California without irrigation. They dug permanent ditches, and ran water through them frequently, to the uncultivated orchard or vineyard.

Soon after the discovery of gold in California and the arrival of the Americans, it was found that surface cultivation would conserve the moisture from the rainy seasons and the second conception was that irrigation was not necessary and was injurious to the fruit crop, that cultivation was the perfect condition and produced the better fruit; these two ideas were not upheld by all growers, some advocated irrigation, others no irrigation, but cultivation.

The result was they found on some land that the non-irrigation failed to produce fruit, while irrigation produced a very successful crop.

They kept watching conditions and plainly say that dormant trees set in the wet season would grow well, and continue through the early part of the dry season, but as the dry season advanced they would stop growing and perish, as the soil moisture became exhausted beyond the

reach of the roots; if the soil was heavy it would become as hard as a rock, if it was light it would become an ash heap.

On the other hand, they saw that where the surface had been mellowed after the late rains had compacted the surface, directly opposite behavior of the plants was seen, the growth was continued, fruit were plentiful, of good size and color; thus they gladly welcomed the fact that cultivation was an advantage over running water over the hard dry soil.

As cultivation proved itself to be a relief from irrigation, providing the amount of rain-fall was sufficient to support a year's growth and fruitage: providing the soil has sufficient retentiveness to hold water from evaporation or leaching; providing there is sufficient depth of soil to form a capacious reservoir.

Thus they found that in order to get a successful crop without irrigation, they must have a deep soil of loam nature retentive to moisture, which was kept cultivated, and especially during the rainy season, so as much of the rain as possible would be taken in and stored instead of being allowed to run off.

The question arises: is it better to apply flowing water or have natural rain-fall? The answer given is that it makes no difference so long as the irrigation is not overdone; the correct amount of water applied either way proves

very satisfactory. Where water is applied from ponds or streams, it contains humus and minerals enough to pay in fertility for its application.

At first there were many objections registered against the fruit grown on the irrigated lands of California, but this was due to the overirrigation which forced too large and soft a growth.

II. EXTENT OF IRRIGATION.

In different sections.

Europe. In Italy irrigation had a very early development and has been practiced yearly ever since.

Mulberry orchards and various kinds of farm crops are extensively grown and irrigated in the Po valley. In Sicily and southern Italy nearly all fruit culture is carried on by means of irrigation. In Lombardy there were under irrigation in 1878, 4,715,000 acres.

In Spain irrigation is very widely practiced on cereals, vegetables, and fruits, farm crops and grass lands, area irrigated reaching up into the thousands of acres.

In France, irrigation was practiced in earliest times, and has been greatly developed; the national government controls some of the largest irrigating canals and systems.

In Switzerland the waters from the mountain streams have been used to irrigate the meadows for many years.

In Belgium the land is naturally very light and sandy and before irrigation practices were begun was practically barren of vegetation. There has been an enormous amount of work done in the construction of canals and the land value has been very greatly increased, because of the increase in its crop producing power under irrigation practice.

In Denmark, irrigation has been used to reclaim the land to a great advantage, increasing land value by nearly one hundred dollars per acre.

In Austria Hungary.

There are portions where irrigation water is conveyed by gravity from the higher lakes, streams, etc., to the grass meadows, and in other portions various methods of lifting the water are used especially for the smaller meadows.

In England, the oldest ruins of irrigation works are of questionable origin, probably being constructed at the time of the Romans in England. Water meadows have been known in the southern parts for many years.

On the continent of Asia, irrigation is practiced in many countries, but India is probably the point of greatest attention both in ancient and modern development. Extensive canals have been constructed and many sources of water developed. In the Island of Ceylong the ruins of irrigation systems have been regenerated.

In Australia irrigation practice is of a more recent origin than other countries, and it undoubtedly will continue on the increase.

In China, canals are established to serve two purposes, transportation and source of water for irrigation practice.

In Japan irrigation has been practiced extensively from time immemorial, as it has in China, irrigation being necessary to produce the maximum of crops on the land to supply the many people. Rice being one of the major crops, there is need of a vast amount of water.

In Africa, irrigation practice has been in operation many years. In Egypt along the Nile River, covering a narrow strip along the river's course. Many artesian wells have been sunk in the provinces of Algiers, Oran, and Constantine. The water found contains nitrates in abundance and this adds fertility as well as water to the irrigated land.

On the Islands of the Pacific Ocean, especially the sugar cane growing islands, as Hawaii, vast systems of irrigation have been constructed and are in use, the yield of sugar cane being doubled by the practice.

On the American continent.

In South America there were extensive irrigation works previous to the occupancy of that continent by the Spanish and Portuguese, on both slopes of the Andean ranges.

In Central America and Mexico irrigation has been more or less extensive since the early history.

According to the statements of Wilson given by King, page 88, area in different sections:

"The total area irrigated in India is about 25,000,000 acres, in Egypt about 6,000,000 acres, and in Italy about 3,700,000 acres.

"In Spain there are 500,000 acres, in France 400,000 acres, and in the United States 4,000,000 acres of irrigated land. Meaning that crops are grown on 40,000,000 acres which, but for irrigation, would be relatively barren or not profitably productive. In addition to these figures, there are some millions more of acres cultivated by the aid of irrigation in China, Japan, Australia, Algeria, South America, and elsewhere."

The amount of rain-fall a section may have during the year does not control the question of whether irrigation shall be used or not; the distribution of the rain-fall during the growing season is the main point. It is necessary in most sections to have a fair annual rain-fall in order to fill the soil and give rise to springs, streams, and wells, or there could be no water for irrigation. There are cases where irrigation water is supplied to a dry country by a voluminous stream from a region of heavy rain-fall, as Egypt is supplied by the Nile River.

In many of the sections where irrigation is practiced there is a fairly heavy and uniformly distributed rain-fall; in these cases irrigation is supplementary rather than absolutely necessary, the increase in water bringing increase in yield of crops and thereby paying for itself.

King, Irrigation and Drainage.

EGYPTIAN IRRIGATION.

Off. Expt. Stas. Bul. 130, pp, 100.

One feature of Egyptian irrigation which is almost lacking in America is the use of water-raising devices; and it is a problem which will have to be solved in the United States, to take the water from the streams.

In Egypt as in America the use of water on the higher lands has ruined large areas of lower lands by raising the level of the ground water, and with it the alkaline salts from the subsoil, and the work of reclaiming these alkali lands has gone much farther in Egypt than in America, considering the fact that a great portion of the land is below sea level and the level of the lakes.

The irrigation canals convey water to the farms, but the irrigation must raise the water for the fields, labor is very cheap and the farms are small, the hoe is the only instrument used in distributing the water over the fields, the water-raising devices are largely worked by hand, as the shaduf and the nati, archimedian screw, etc.

Many of the irrigation structures of Egypt are models of their kind, such as the dams, head-gates, waste gates, etc.

The regulators and bridges of the larger canals will always be objects of study for irrigation engineers of other countries.

The question in Egypt is to store the water which the Nile carries during its flood season. If this can be done, there will be an ample supply and in a few years the demand for land will exceed the demand for water. With us the area of irrigable land will ultimately be limited by the water supply.

Early irrigation in California:¹ when the adventurous missionaries pushed their way through to the Pacific coast, they taught the Indians the crude art of irrigation as they went, thus starting the first small impulse toward the conquest of California's fertile soil; with the early churches and gardens, the skill and labor required to build the first rude furrows are now of little importance in comparing with the monumental engineering works which succeeded them, and they are an insignificant feature in a landscape which now includes miles upon miles of cement-lined aqueducts, scores of pumping stations, and acres upon acres of orange and lemon orchards cultivated with great thoroughness and skill.

For the beginnings of Anglo-Saxon irrigation in this country we must go to the Salt Lake valley of Utah, where, in July, 1849, the Mormon pioneers turned the clear waters of City Creek upon the sunbaked alkaline soil, in order that they might plant the very last of their stock of potatoes in the hope of bringing forth a crop to save the little company from starvation. Utah thus is the

1. Yearbook, 1899, 591-612.

cradle of our modern irrigation industry.

The Mormon church had a great influence upon the first settlers; helping them organize and fighting together for eachother's good and the maintenance of all, the constructed an irrigation canal, divided their farms to about thirty acres and each farm grew enough produce to be self-sustaining entirely, due to the use of water.

The discovery of gold in California started the overland march, and began operations there. The Union colony of Greeley, Colorado, became the second historic instance of the beginning of the present system. Utah was the result of a religious immigration, Greeley the creation of a town meeting, and starting home making in Colorado. Cooperation was adopted in the construction and management of public utilities, and the irrigation canal was one of the first.

Irrigation in California started in a corporate and speculative way, the intentions of a few to get rich by renting or selling water rights, and collecting toll annually from the water tenants.

The investment of corporate capital in canals to distribute and control water used in irrigation thus started in California, and spread like contagion throughout the West, and for a number of years was the leading factor in promoting agricultural growth of the western two-fifths of the United States. It has been the agency through which many millions of dollars have been raised and expended,

hundreds of miles of canals constructed, and hundreds of thousands of acres of land reclaimed.

These corporate canals have in most cases represented a great loss to their builders, due to the long delay in getting settlers and to the very limited means of those who did settle.

In the Artesian basin of South Dakota.

The method¹ employed in irrigating varies somewhat with the crop. For small grain fall plough and flood, soaking the soil well but not allowing water to stand. In ordinary years this is sufficient but in a dry season another watering is given just as the grain is beginning to head. If applied much earlier than this the ground not being sufficiently shaded by the foliage is apt to bake and form a crust over the surface. If watered later, it retards the maturing of the grain and impairs its quality. The effects of over-irrigation have been shown very plainly in this section.

The market gardeners have been most successful financially, their methods vary with different crop and seasons, having the soil well moistened at seed time to hasten germination. After that they watch the crop and water when it is necessary, following by cultivation.

The objections to artesian water are the salts it contains, but these have proved ineffective only when

1. Off. Expt. Stas. Bul. 148 (Crane).

irrigation is carried on when they prove injurious, the frequent rains wash away any accumulation of these soluble salts.

The salts in the waters and those drawn from the land have not thus far had any detrimental effect, nor do they give indications that they will have in the future. All cases of deterioration of the soil are directly traced to the oversupply.

In extraordinarily dry seasons the water from these wells increases the crops two or three times, and the crops are always of a better quality.

A good two inch wekk supplémented by a reservoir will supply one half a section.

The artesisn basin comprises that area in which flowing wells have been obtained by drilling down into the Dakota sândstone formation that underlies almost the entire state of South Dakota.

Owing, however, to the greater number of wells and the ease of getting water, the James River valley is called Artesian Basin, and it is within this region that almost all of the experiments in irrigation from artesian wells have been conducted.

From 1880 to 1894 quite a number of wells were sunk with the intention of using them for irrigation; they were mostly six inch wells sunk from five to thirteen hundred feet and costing from twenty-five hundred to four thousand dollars. These wells did not prove successful under the tenant system

of farming and most of them resulted in a financial loss to the original projectors and were given up.

Then a new system was started; one and a quarter inch wells were sunk at a cost of three to six hundred dollars and were within the means of most of the farmers.

A two inch well costs sixty cents a foot. The duty of the artesian water is to supplement the rainfall.

In Italy.

Most¹ of the actual use of water in Italy is controlled by associations of irrigators; some control whole systems of canals, while others operate single laterals.

The Italian government owns the water of the streams and certain canals which are controlled by the Minister of Finance and his subordinates. Canals are leased from the Government, and they must be kept in repair by the lessee, the government thus playing an important part in the helping to advance irrigation.

Irrigation in the Yakima Valley, Washington.²

This is a region of many acres of fertile soil which could be made to produce very profitable crops if plenty of water were only available, which is now standing idle only waiting for water.

1. Off. Expt. Stas. Bul. 190.

2. Off. Expt. Stas. Bul. 188.

In Persia where the excessively heated atmosphere evaporates surface water very rapidly, irrigation water is applied to the fields by gravity. Series of wells are dug on the hillsides connected by underground tunnels. In this way the exposure to air is greatly decreased and irrigation made possible.

II. 3. EXTENT IN UNITED STATES.

In the Arid States.

In 1899 there were 102,819 irrigators and 7,263,273 acres of land irrigated at a cost for irrigation systems of \$64,289,601.

The arid states as considered are Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, and Wyoming.

The crops irrigated in these states are hay and forage, cereals, vegetables, orchard fruits, and other minor crops.

Hay and forage is the more important item, being over one-third of the whole area irrigated, showing that irrigation in these states is an adjunct of stock raising.

"The most important function of irrigation, next to raising hay and forage for the winter feed of cattle on the public range, is the production of vegetables, fruits, and miscellaneous crops."

In these arid states the greater part of the irrigation water is taken from the streams, a small percent coming from wells.

The tendency at first was for large farms, but the size has decreased and intensive culture is practiced.

According to the census of 1900 there were in the state of:--

Arizona	183,396	acres irrigated	
California	1,446,114	"	"
Colorado	1,611,271	"	"
Idaho	608,718	"	"
Montana	951,154	"	"
Nevada	504,168	"	"
New Mexico	203,893	"	"
Oregon	387,095	"	"
Utah	629,293	"	"
Washington	135,470	"	"
Wyoming	605,878	"	"

Arizona.

When the Americans or rather the white men entered Arizona, they found the Indians practicing irrigation in a primitive form. There are two clearly defined regions in the state, the higher and lower. The higher plateau where the elevation is 3000 feet, has a rainfall insufficient to crop production, while the lower section has sufficient rainfall to grow forage crops.

There are two river systems, the Colorado and the Gila. The Colorado has cut such deep channels through the high plateau that its waters are rarely available. That portion of the state where irrigation is most largely carried on is the water-sheds of the Gila, where extensive canals and ditches have been constructed. This portion of the state resembles Southern California, and without irrigation it is a semitropical desert; with irrigation it produces crops to sustain a dense population.

Census XII, IV, p. 823-826.

California.

In this state there is a great variation in topography, soil and climate. The greater portion of the land will produce crops without the artificial application of water, but due to the intensive culture of orchards and other crops, irrigation systems are established as an insurance in case of drought.

Due to the mountain ranges there are many streams and lakes, and water is easily available from these, while in some places wells are dug and pumping systems constructed. There are also many canals and ditches.

Water from underground sources is obtained by pumping from wells, driving tunnels into the sides of hills and mountains, and from flowing wells.

Windmills are used very little.

Centrifugal and rotary pumps are employed, the fuel used being very largely oil and wood.

In Nebraska¹ and Colorado, in the lands of the South Platte Valley, the rights to be supplied by water are ten times the supply or the average flow of the streams from Spril to September.

Rights to water are theoretically based on use, courts decree water rights.

In Colorado, Wyoming, and Nebraska the priority rule is followed, any man who had dug a ditch and improved his land was given the superiority of the right to use water over the later comers.

Justice and public welfare demands of these priority holders, however, that they take only what water they can use beneficially. Water rights are lost after ten years' nonuse.

Water rights in Nebraska and Wyoming grant sufficient water to irrigate a certain area, not stating the volume.

The largest water rights are held by canal companies who control nearly 60,000 acres of land.

Whalan Falls Canal Co. and Fort Laramie Canal & Reservoir Co. have pending rights which will undoubtedly equal eight hundred cubic feet of water per second, from the North Platte River.

Colorado.

In² this state no riparian rights are recognized, priority is upheld. Appropriation is considered a natural right and is declared not to be denied so long as there is

1. O. E. S. Bul. 157.

2. Off. Expt. Stas. 157, p. 80.

unappropriated waters in the streams.

The¹ greater portion of the irrigation water is derived from streams, wells are used to some extent, the underflow being reached at from 20 to 1500 feet.

Ditches and canals receive water from the Platte River and its tributaries, reservoirs have been built by individuals and corporations to store the fluctuating flow of this river.

Beside the Platte there are the Arkansas, Rio Grande, Grand, Green, and White River basins furnishing water.

In² this state it can never be expected to get water enough to irrigate all the land.

In 1898 there were some 2,000,000 acres irrigated, with water rights value 30,000,000.

Idaho.

A³ part of the northern portion of this state is humid while the remainder is arid. The Snake River having its source in the Yellowstone National Park furnishes the greater portion of the water used in irrigation. And with more judicious practice in the use of water, a vast area of now uncultivated land could be made available to crop production.

1. Census XII, II, 831-837.
2. Nevada Bul. 52.
3. Census XII, Vol. 4.

Montana.

The¹ Missouri River basin practically includes two-thirds of the state.

The main range of the Rocky Mountains crosses the northern portion of the state, and its heavily wooded slopes furnish a source for several mountain streams which combine to form the Missouri.

The state as a whole is not so badly in need of irrigation, as those states as little farther south.

There has been a rapid increase in the farm wealth of the state, due to the successful application of irrigation to the crops.

Crops grow quite successfully without irrigation, but there are portions of each growing season when irrigation produces an increase of production, acting as an insurance.

Nevada.

This² state is perhaps the most arid in the Union. There are very few settlements and those almost entirely the homes of miners and ranchmen.

Irrigation has developed to some extent along the Humboldt River, where reservoirs have been constructed and some crops are grown.

The Truckee, Carson, and Walker Rivers furnish water spasmodically and if preparations were made to store it, conditions would be greatly improved.

1. Census XII, vol. 4.
2. Census XII, II.

Springs furnish water for the ranches, but no great attempts have been made to sink wells, and no great agricultural development has taken place

Nevada¹ is a state which is dependent upon irrigation, the rainfall varying in different parts from 15 to 18.38 inches.

The irrigation supply comes from the melting of snow on the mountains.

The main portion of the work in Nevada up to 1901 was the finding of the amount of water available for irrigation and the possibility of getting it to the land where it was to be used.

New Mexico.

Agriculture² in this state in 1900 was just beginning to take a stride toward great improvement; there are many rivers and great opportunities for improvement by the construction of reservoirs and the careful application of the water.

An³ ample quantity of water for irrigating exists at a shallow depth in the Rio Grande valley in southern New Mexico available by sinking pipe wells. Six inch wells 48 feet deep at Mesilla Park gave 1000 gallons per minute.

1. Nevada Bul. 52.
2. Census XII, II.
3. New Mexico Bul. 45.

Oregon.

The ¹Cascade Range divides this state into two sections of very dissimilar characters as to topography, soil, and climate. There is a heavy rainfall and irrigation is not necessary for general field crops, irrigation being used at times during the summers for vegetables and some for hay. The irrigation systems are very largely individual and inexpensive.

Utah.

"The ²beginning of irrigation wisdom is the conservation of the natural precipitation."

Irrigation should be supplementary to the natural precipitation; the first thing for the irrigation farmer in Utah to consider is the proper storage of the rainfall and snowfall in the soil, and then the water right in the canal above his farm.

The natural precipitation over the larger portion of the Great Basin, if properly conserved by summer fallowing, is sufficient to produce crops without irrigation.

The amount of moisture found in the soil in the fall depends on the crop grown, the total amount of water applied during the season, the summer precipitation, and on an irrigated farm, on the date of the last irrigation.

On an irrigated farm as high as 95.56% and on non-irrigated farms as high as 93.17% of the total winter precipitation were found in the upper eight feet of soil.

¹ Census XII TT

² Utah Bul. 104, Nidstoe.

The average per cent of winter precipitation found in the upper eight feet of soil for five years on an irrigated farm 82.13. On nonOirrigated farm just reclaimed three years 61.85.

From the fact that the eighth foot becomes dry as the growing season progresses, we have the right to infer that water is drawn by plants from below the eighth foot. Just how far down the action of the plant roots is felt upon the soil moisture film is not known, However, it is certainly below eight feet and it is not improbable that it is at least twelve to sixteen feet.

The drier the soil is in the fall the more of the winter precipitation is found in the first eight feet of soil.

The water capacity of soils under field conditions is usually eighteen per cent.

A considerable portion of the winter precipitation passes down through the soil below the eight foot limit.

Fall ploughing tends to conserve the natural precipitation.

Summer fallowing conserves the soil moisture the longer the fallow period, and the higher the per cent of soil moisture."

Utah.

About¹ one half within the bounds of the Great Basin the rivers have cut deep conyons through the plateaus, thus making their waters only available in certain places.

The Mormons began the practice of irrigation in this state, and since that time much work has been done by the Government, and many reports made of the progress.

Washington.

The Cascade Mountains divide this state into humid, semi-arid and arid portions. On the arid portion great irrigation progress has been made.

Wyoming.

When¹ Wyoming became a state the constitution declared all unappropriated water the property of the state, and it could only be appropriated upon application to the state through the state engineer, who would issue a permit. There are no riparian rights given and the only thing considered is priority in appropriation. Water rights may be sold separate from the land sale, providing there is no injury accrued on any of the other irrigators holding water rights.

In this state there are almost unnumberable streams from the mountains and thus irrigation is proportionately easy, the greatest development having taken place where cattle raising is the principal industry.

1. Off. Stas. Bul. 157.

EXTENT IN THE SEMI-ARID STATES,

According to Census of 1900.

Kansas	total area irrigated	23,620 acres
Nebraska	" " "	148,538 "
North Dakota	" " "	4,872 "
Oklahoma	" " "	2,759 "
South Dakota	" " "	43,676 "
Texas	" " "	49,652 "

The greatest amount of irrigating is done when the water can be taken from the mountain streams, a very small proportion being taken from wells.

Kansas.

That portion of Kansas lying west of the one hundredth meridian, and some parts extending east of it, belong to the semi-arid region where irrigation is necessary.

The history of irrigation in the state of Kansas has been marked by a number of failures. At first settlement was encouraged far into the plains region by a series of wet years, companies advanced money on the land, dry years came, the settlers were unable to produce crops, gave up their homes and departed, leaving their land to these companies who had furnished money. The companies then built immense canals and irrigation systems flooded the land, and were ready for a complete success, but they had not considered the volume of their supply streams, and the result was their

canals were full when not needed and when most needed they were empty. New steps had to be taken then to construct reservoirs, and to use methods of raising the ground water, which is found throughout the state at varying depths.

Nebraska.

This state lies in two distinct regions--the humid and arid. East of the one hundredth meridian the rainfall is usually sufficient to insure the successful cultivation of crops, proving very satisfactory with the aid of irrigation for the dry times.

The western part of the state is typical of the Great Plains country, and here is where the greatest development of irrigation has been made.

The Platte River furnishes some water the year around and ground water can be reached at depths from ten to three hundred feet. Windmills and reservoirs are used.

North Dakota.

"Irrigation in this state is confined almost entirely to the northwestern part of the state, and is not generally practiced even there." The greater portion of the water is taken from streams, while some is taken from wells; the leading crops irrigated are pasture and wild hay land.

Oklahoma.

The Black Hills country in the western and southwestern parts of the state represents the area irrigated.

The Cheyenne River, rising in eastern Wyoming, flows through South Dakota, but its flow is very spasmodic. There are two tributaries rising in the timbered area of the Black Hills, however, which carry a continuous stream.

The supply is not nearly sufficient for the land under ditch, but it could be increased greatly by the construction of reservoirs to hold the heavy flow at times, after rains, etc.

Texas.

This¹ state has a large portion humid and a large portion semi-arid to arid.

Irrigation is not very extensively carried on. The waters arising in New Mexico are alkaline, so they cannot be used.

In² the Pecos valley up until 1889 irrigation was found only in a few small places where ditches had been taken out of the streams.

The only settlers were cattle men and they tried their best to discourage general farming. At Roswell the permanent water of the spring rivers and the ease with which it could be put on the land encouraged the most extensive farming.

In 1889, encouraged by the success of irrigation in Arizona, and Southern California, a large company was formed to develop the Pecos valley, and the present systems of irrigation are in a great measure the result of the investments made by this company.

1. Census 12.

2. Division of Soils, 1899.

IRRIGATION IN HUMID STATES.

The twelfth census was the first to take into consideration irrigation in humid states, and the first attempt shows that there are a large number of farmers in the so called humid climate who place dependence upon an artificial supply of water.

Humid states considered:--

Connecticut	Acres irrigated	471
Florida	" "	1483
Maine	" "	17
Massachusetts	" "	134
New Jersey	" "	73
New York	" "	68
Pennsylvania	" "	864
Rhode Island	" "	40

In Connecticut the greatest extent of irrigation is on the bottom lands edging the streams, where little cost is involved in the operation.

In Florida the practice was started by the orange growers, who were so successful that it was taken up by those interested in truck farming. Florida has an annual rainfall quite sufficient but it is subject to drought during the growing season.

The state is underlaid by artesian waters at depths of from twenty-five to five hundred feet, so that when wells are bored, most of them flow with considerable pressure and great volume, so that in most cases there is no cost from pumping.

Maine.

Irrigation is only reported from eleven farms, the water being pumped from wells, and applied through hose.

Massachusetts.

Nearly all the irrigation reported was on garden produce.

New Jersey.

Very small and quite general.

New York.

Very little reported in comparison with what the next census will show.

In Pennsylvania irrigation has been practiced since 1800 to some extent.

The southern rice-growing states have extensive systems of irrigation.

The water used on several rice fields of Louisiana and Texas, measured in 1903 and 1904, compared with measurements taken 1901-1902 should a tendency to use less water. Deep coverings of water found to keep soil cold and to produce ~~s~~spindling plants.

In¹ the Hawaii Islands, it is necessary to irrigate in order to grow the sugar cane, flooding and furrow irrigation being used. Irrigation has been carried on so extensively that beautiful springs are breaking through the ground at the lower points of the land.

These excesses of water have carried away a large amount of the fertility which these deep virgin lands contained before irrigation started, as an accumulation formed during the years of no leaching rains.

Experiments seem to show that the best results are obtained in the arid regions by giving the land thorough soakings at considerable intervals of time. In the humid regions, however, it is not uncommon to get sudden showers of an inch or more followed perhaps by a day or more of stormy weather; if this comes just after a thorough irrigation of an inch or more, there is a possibility of a decrease rather than an increase in crop production, as excessive moisture during a time when the air is also heavily laden is very conducive to spore germination and this to the establishment of disease and its spread. This does not apply to such crops as the cereals and grasses, but more especially to vegetable crops, as cucumbers, potatoes, beans, etc.

When² irrigating under humid conditions there should be good drainage, the soil should be light sand and that which is producing high priced crops. It has been said that the value of the crop should be at least fifty dollars per acre.

In humid regions irrigation is always a supplement to the natural rainfall and is not generally applied in any such large quantities as in the arid West.

The regions in the East where irrigation has received special study are New Jersey, New Hampshire, Louisiana, Ohio, and Wisconsin.

III. PROVISION OF WATER FOR IRRIGATION.

1. Source of water.

It¹ is a trite saying that the water of the land comes from the air. Three thousand years ago the circulation of moisture has been observed. The evaporation from the sea, the winds blowing the vapors inland, the precipitation as rain and snow, the running off as springs and rivers back to the sea, have all been known for ages.

There is an opinion prevalent among the settlers on the plains that the sheet water located in the porous tertiary beds forms a continuous sheet from north to south as well as from west to east, but this is true only to a very small extent, as the great valleys effectually cut off such connection of the sheet waters.

The plateau on which the Frenchman River makes its shallow mark has the largest area uncovered by marl, the porous grit here exposed and its own sedimentary soils, almost as porous as the porous sand hills resting on this plateau, all combine to make the region a most certain source of subterraneous water supply. When rain comes it is almost all absorbed. The surface imbibes it and the pores below carry it down to the storehouse beneath. Evaporation gets a relatively small part of this water, The heaviest storms rarely raise a stream in the gullies, the absorptive power of the sod is so great.

The Frenchman has never been known to have a flood, yet its flow is constant because of this imbibition, and its source is from a steady outflow.

The ultimate source of the water is the rainfall and it has been shown that some large areas north of the Frenchman have this imbibition power.

The Frenchman River runs through Colorado and Nebraska.

There² are in the western states still vast areas of land which are valueless on account of the lack of water. The future utilization of this vacant land depends largely upon the water supply, and upon the intelligent regulation of the same, based upon a thorough knowledge of the resources of the country and its limitations in this regard.

STREAMS; WELLS; AND STORED WATER.

Surface streams are the most important since they furnish the greater part of the water, and render valuable more than nine-tenths of the land now reclaimed by the artificial application of water.

The small mountain streams of the West are really the valuable ones, as their flow can be cared for with small ditches. The larger streams are almost uncontrollable, and no great development can take place except through the state or government intervention.

Although the greater part of the land made valuable by the artificial application of water is dependent upon streams, yet wells play a very important part as sources of water.

Two classes of wells.

1. Geol. Survey 16, Part 2, pp. 535-588. Robt. Hay.
457-533. F. H. Neneil.

Artesian or flowing, and those from which water must be pumped or lifted by various devices.

Experience has shown that a farmer who will content himself with a few acres and utilize his resources to the best advantage can make a good home and living upon the arid or semi-arid lands by means of agriculture rendered possible by means of water pumped from a well.

The greatest trouble in the dry West has been the attempt by the farmer to lay claim to and cultivate vast areas.

Artesian wells have attracted considerable attention but they are probably of less real value than other wells on account of their continuous flow, making swamps, depositing salts, their very convenience being their downfall.

The artesian wells of the country as a rule gradually decrease in the amount of water delivered and in pressure. This decrease is generally due to mechanical defects in construction or accidental injuries more than to the drawing down of the hydrostatic head.

Reservoirs.

In the arid sections the mountain streams flow full during the spring and later in the season they are practically dry. Reservoirs are built to hold over some of this supply from the time when there is an over supply until a dry time; at first these reservoirs were built up toward the head of the stream, and at some distance from

the owner's land; as a result when the reservoir was opened the above neighbors could help themselves and irrigate their fields first. This led to the building of the reservoirs in the low lands where they were really not successful unless they were owned by a company of irrigators along the stream and the reservoir was made large enough to supply all.

In¹ portions of Kansas, Nebraska, and Colorado, the water supply may be considered under two heads:

1. The visible or surface waters.
2. The invisible or subterranean waters.

The visible waters may be again divided into lakes, streams, and springs.

Lakes exist only in years of more than average rainfall.

Streams arise in the mountains from springs, etc.

Springs are not very abundant on the ranch land, and there are very few which are copious.

Underground waters.

1. Underflow of the valleys.
2. Sheet water of the highlands.

The sandy character of the valleys allows considerable underground storage of water. Occasional beds of clay separate the water into two or three sheets which coalesce into one thicker vein around the edges of these clay deposits. Where there are more veins than one the waters in the lower ones usually rise to the level of the highest when a boring reaches them.

In the states Utah, Colorado, and Nevada the water for irrigation purposes is almost entirely supplied by mountain streams.

East of the Mississippi River, the majority of irrigators are dependent upon windmills, hydraulic-rams, steam pumps, gasoline pumps, etc.

In Connecticut as many of the eastern states, there are small natural streams, ponds, springs, etc., from which water is pumped for irrigating purposes. Many farmers dam the flowing streams, thus making a storage pond where they reserve the water until it is needed.

Possible sources.

1. Diversion of perennial streams.
2. Development in dry stream beds.
3. Development of springs.
4. Catchment from outcropping of water-bearing strata.
5. Tunneling to intercept such strata when deeply covered.
6. Flowing wells.
7. Pumping from wells, lakes, streams, springs.
8. Storage of storm water from surface flow or from drainage systems.
9. City water.

1. A simple method of damming a constantly flowing stream and causing the water to flow off into side channels which have been constructed to lead the water where it is desired for use.

2. A dry, stream-bed is generally a very fertile spot of heavy moisture-retaining soil, and crops will grow here with great luxuriance.

3. Springs are outcroppings of water from some higher level, appearing where there may be a break in the strata covering.

4-5-6. Simply means of getting at the underground water layers and bringing them into use.

7. There are many methods of pumping, there having been quite an evolution of forms of pump.

By pumping we mean raising water from a lower to a higher level. The first means of accomplishing this feat in Europe was two men with a woven basket-like tub, this lead up to the shaduf and their arrangement in series up a bank, a form of our old well sweeps. Animal power succeeded human power, followed by wind power, and mechanical contrivances as rams and engines.

8. Storage of water from storms and surface flow is a very important point since such flow is almost always greater during the season when it is not needed for crop irrigation, and should be held over.

9. City water can be used where it is possible and is used quite generally by truck gardeners in the vicinity of cities.

III. 2.

IRRIGATION WORKS.

A well¹ sunk at the New Mexico station cost \$150.00, and with a 20-horse-power engine could irrigate land three inches deep at a maximum cost of 51 to 64 cents an acre where short runs were used.

There are 6,272,640 square inches in an acre of land. There are 231 cubic inches in a gallon. Twenty-seven thousand one hundred and fifty-four gallons will cover an acre one inch deep. A twenty-five horse-power motor will pump one thousand gallons a minute and raise the water fifty feet. One thousand gallons a minute for twenty-four hours will cover fifty-three acres one inch deep. Fifty-three acres a day for seven days equally three hundred seventy-one acres.

Use² of windmills for pumping.

Windmills may be used to pump water from canals, ditches, reservoirs, lakes and wells, and when the wind blows ten to fifteen miles an hour they may be satisfactory, but for irrigation, a thing which must be done at a certain time, they are not to the best as they are at the mercy of the wind; without wind they are useless.

In Southern California, deep well pumping by gasoline engines is used to good advantage, both as individual concerns and as companies for profit where the water is sold.

Small electric pumping plants are used when electricity is available for power purposes, its advantages being that

1. New Mexico Bul. 45.

2. Yearbook 1907, pp. 409-424.

it can be started quickly and easily and it will run continually or intermittently as desired, doing very good work, at a slight cost for maintenance. Cost this methos: \$1.85 per acre foot of water or \$3.70 per acre per yard.

In¹ Santa Clara valley, one of the leading fruit regions of central California, there were in 1900 about 1500 irrigating plants of all kinds. About 900 of these were established since 1897.

Many of the systems have centrifugal pumps run by steam, the larger of which are from four to twelve inches, being operated by engines of from fifteen to forty horsepower, the water being drawn from wells from 100 to 500 feet deep. Small gasoline pumps are also ysed.

ORGANIZATION OF THE RECLAMATION SERVICE.^I

Major J. W. Powell in his book entitled the "Lands of the Arid Region" started the movement. He kept the matter agitated before the government, and in 1888 he, as Director of the Geological Survey, was authorized to investigate the extent to which the arid region might be reclaimed by irrigation. He mapped the mountainous catchment basins of the streams and located the irrigable land.

In 1894 an appropriation for gauging streams was made, and work was extended from time to time until a large amount of general information was at hand concerning the

1. Farmers' Bul. 116.

I. Third annual report of the Reclamation Service.
1903-4. Second edition.

arid West and the opportunities for its development under irrigation practice.

When the reclamation law went into effect on June 17, 1902, there were a small corps of engineers comprising what was known as the division of hydrography of the Geological Survey, and these men became the nucleus of the Reclamation Service, which was organized for administrative purposes as part of the Geological Survey. The working staff has been increased.

THE RECLAMATION LAW. Approved June 17, 1902.

An¹ act appropriating the receipts from the sale and disposal of public lands in certain states and territories to the construction of irrigation works for the reclamation of arid lands.

Previous laws had provided for five per centum of the sales for educational purposes.

The states and territories concerned in this act were the eleven arid states and five semi-arid, leaving out Texas, in all then thirteen states and three territories, making a reclamation fund in aggregate for the sixteen for the years 1901 to 1904 inclusive, \$23,270,592.63.

Under section nine of the law there is a provision that the funds arising in each state or territory shall be divided into two portions, a major and a minor portion, and that the major portion 51% shall be expended in the state

in which it arises wherever it is deemed most necessary through competitive examinations under the civil service law.

Sections.

1. Funds for Reclamation.
2. Examination and Surveys.
3. Withdrawals of lands.
4. Construction and charges.
5. Defines payment; matter of reclamation owed personally.
6. Operation and maintenance of works.
7. Condemnation proceedings.
8. State Laws.
9. Distribution of expenditure.
10. Rules and Regulations.

The Reclamation Fund has amounted to over \$60,000,000, and is being added to at the rate of six or seven millions a year. It has been invested in the construction of reservoirs, canals and distributing systems, and already twenty-seven projects have been initiated or completed, works having been undertaken in each of the western states and territories.

Over a million acres have been reclaimed. Reservoirs have been built with a capacity of 5,000,000 acre-feet, or water sufficient to cover 5,000,000 acres of land one foot deep.

Canals large and small, tunnels, bridges, culverts, headgates, siphons, etc., have been built to an enormous extent.

Nearly 60,000,000 cubic yards of earth and 10,000,000 loose and solid rock have been excavated.

Value of crops raised in 1910 nearly \$20,000,000.

Land values have increased from practically nothing to \$100,000,000, and these values will increase as the work nears completion.

III. 2. MEASUREMENT OF WATER FOR IRRIGATION UNITS AND METHODS.

Acre foot 325,851.45 gallons.

The amount of water required to cover an acre one foot deep equivalent to 43,560 cubic feet, a simple and a definite unit.

Second foot.

The flow of one cubic foot of water each second, sixty-two and one-half pounds of seven and eight-tenths gallons each second. A convenient method for stream measurement, a stream one foot wide and one foot deep, flowing at the rate of one foot per second.

A second foot flowing one day will deliver 86,400 cubic feet of water, or an equivalent of 1.983471 acre feet.

Miners inch.

The amount of water which will flow through a hole one inch square under a uniform and designated pressure; different states have different pressure requirements. Generally a head of six inches and flowing through the year.

50	California	miners	inches	equals	one	second	foot.
38.4	Colorado	"	"	"	"	"	"

The miners inch is an indefinite quantity, coming to be regarded as the one-fiftieth part of a second foot.

The cubic foot per second is a definite and convenient unit of volume.

For measuring the flow of a stream there are various forms of meters. At the Wyoming station the Nilometer and the weir are used; the Mead water regiester and weir; clock arrangements with record sheets.

III. 5. LOSSES OF WATER IN DISTRIBUTION.

Reservoirs and Canals.

Ways in which losses may occur.

Seepage from ditches, evaporation from water surfaces and from the wet soil, but percolation beyond the reach of the roots of the plants, and by waste which may seem necessary to properly wet the soil.

Sunshine¹ is a strong factor in causing a loss of soil moisture; relative humidity, sunshine and temperature, and winds.

Utah Bul. 39. A. A. Mills.
Geo. Survey 14-2, pp. 100.
F. H. Newell.

1. Utah Bul. 80.

Evaporation¹ and seepage from canals. there may be a loss at one point and a gain at another point in the same canal due to seepage and the elevation of the soil.

Losses from evaporation are relatively small compared with losses from seepage.

Losses in clay soils are less than in sandy soils or gravelly soils. Loss in carrying water in small quantities is relatively larger than from large quantities. A small head of water is wasteful, and loss decreases as an impervious lining is formed. Cement linings do not last in Colorado. A low estimate of the yearly loss of water from Colorado canals is ten million dollars.

3. Losses² of water by seepage and evaporation.

Extensive losses from seepage injure canal companies by lessening the amount of water they can deliver, and often injure farmers by the water which seeps out from the canal, finding its way to the surface where it is not needed.

The average losses by seepage and evaporation found in 1900 from different canals varied greatly. The average rate of loss per mile was 2.47 per cent, A vast difference was shown from month to month and year to year. If a rate of loss such as this should remain uniform throughout the length of a canal, it would mean at the end of forty miles the canal would be dry.

1. Colorado Bul. 48.

2.

The loss from canals is found to be largely from seepage as in the cement lined canals where the loss was only from evaporation it was comparatively insignificant. In summer when the water becomes heated in its transit through the canals and laterals, and when turned on the hot, dry surface of the fields, a very large per cent goes up into the air.

Thus the loss from seepage must be looked for in the main canals, the losses from evaporation in the laterals and on the fields.

IV. APPLICATION OF WATER.

Duty of Water. Amount Required for Crop Production and Factors Affecting.

The duty of water means the area or acreage of land which may be irrigated with a given quantity of water, as a cubic foot per second, or a miners inch.¹

This is a very important subject to irrigators, and one on which it is indeed difficult to get data which is entirely satisfactory and trustworthy, due to its general character. Where water is used from canals some of the conditions which help to make any available data uncertain are, water lost by seepage and evaporation from the canal and its distributaries Before the land to which the water is to be applied is reached, is so variable and indeterminate that it makes any data only a rough approximation.

If there was a sufficiency of exact data at hand covering a wide range of conditions, it would still be necessary to make great allowances when specific applications were desired, because of variations in weather, climate, crops, soils, and degrees of skill in applying.

General statements are helpful but no fixed rule can satisfy all conditions.²

1. Nevada Bul. 52.

2. King, Irrigation and Drainage, 209.

Duty of Water.

Amount of land which can be irrigated with a given quality of water, or the relation which these bear to each other.

The investigation of the duty of water is one of the most complicated problems of irrigation, on account of the diversity of conditions and the difficulty of procuring facts. There is such a difference in methods of measurement, localities, soils, crops, application of water, and frequency of watering that the statements made by different persons are almost irreconcilable. In general, more water is used (the duty less) on the newer land than on that which has been cultivated by irrigation for some years, and more is used where water is plentiful than where it is scarce.

The amount of water which must be applied to the land artificially in order to produce crops varies from none where is sufficient rainfall, to the maximum amount where there is practically no rainfall.

In¹ Italy where irrigation has long been systematically practiced, it is generally calculated that one cubic foot per second of water will serve satisfactorily fifty-five acres of land, making if fifty-one and two-fifths acres to allow for evaporation and seepage. Or 4.63 inches of water every ten days during irrigating season.

Rice irrigation in Italy receives on an average 5.55 inches every ten days during irrigating season.

Census XII, Vol. 6, 818.
1. King, 209-217.

In Spain where there is less rainfall than in Italy 2.353 inches every ten days.

In Egypt, winter applications 3.937 inches once in forty days, summer 4.528 to 3.412 inches, cotton requiring twice this amount of 1.706 inches per ten days, rice 3.412 inches ten days, maize 2.276 inches every ten days.

Tables given covering 100 cases from all parts of the world, average taken for the general crops excluding rice, sugar cane and water meadows, a cubic foot of water per second is made to serve 117.6 acres equivalent to 20-24 inches of rain during a season of 100 days covering surface 2.024 inches every ten days.

"Three hundred¹ twenty-five to five hundred fifty pounds of water will produce a pound of dry matter in the humid atmosphere of Wisconsin; an average of seven hundred fifty pounds is required to produce the same amount in the climate of Utah, showing the increase required due to evaporation. In the hot and dry climate of the Hawaiian Islands, two hundred eighty-five to four hundred and fifty pounds of water are required to grow one pound of sugar cane, while in Utah over four thousand pounds of water has been absorbed by the crops and air in growing one pound of wheat. No definite estimate that might be made could cover the quantity of water required for the irrigation of crops in the same or different sections for different seasons and different times in any section.

The amount of water varies with the locality with the season. At the same place and during the same season it varies with the nature of the soil, method of application, degree of skill exercised by the irrigator and kind of crop irrigated.

In the so called humid states, although the annual rainfall may represent conditions very favorable to crop production, it is a question of distribution through the growing season.

In New Jersey, the rainfall runs from 49.7 inches on the seacoast to 31.05 inland.

Lowest amount found from April 1 to August 1, 1880-1895 was 9.33 inches. In Southern New Jersey an equivalent of 12 inches is required for the whole growing season, certain years on certain months four inches will thus meet the deficiency. Thus the irrigation problem is more complicated in the East than it is in the West or arid regions, since in a certain number of years very little may be required, while other years the entire 12 inches may be required; irrigation capacity must therefore be large enough to meet the maximum demands although the maximum demands will not be made according to records more than once in three years.

Factors affecting irrigating are thorough cultivation to conserve both natural and artificial, water applied, character of the soil and subsoil, depth of ground water, slope of land, etc.

Voorhess, N. J. Bul. 87, 40-48.

The amount of water required to produce paying yields of any crop is a complex and an important problem.

A given quantity of water applied to the soil in any way, either rain or by irrigating, renders greatest service when the whole of it is taken up by the roots of the growing crop.

Were it possible to establish and maintain field conditions of culture which would insure that all water lost from the soil should take place through the foliage of the crop being fed, then a very small amount of rainfall during the growing season would suffice for the production of large yields.

Thus the duty of water in crop production is determined by the natural losses, as transpiration through the plant, evaporation from the surface of the soil, and by drainage both surface and under. And the more these sources of loss can be curtailed the greater will be the duty of water in any region.

In countries where irrigation is absolutely necessary to grow crops, proper management can make the loss from evaporation and drainage very slight, the same may be accomplished in humid sections.

CONDITIONS WHICH MODIFY THE DUTY OF WATER.

1. The peculiarities of the crop grown, such as the number and size of the breathing pores of the green parts of the plants. The character of the foliage as to whether

it produces much or little shade. The length of the roots, deep rooted plants are able to take more water from the soil than are shallow roots.

2. The character of the soil.

From the standpoint of the water company and irrigation engineer, the size of the soil particles is important, since water passes through or percolates through a coarse soil much faster than through a fine soil; important to canals.

The grower regulates evaporation by means of mulch and experiments show that a mulch formed by stirring the soil to a depth of four inches is very much more efficient than one inch, and that there is approximately one third as much loss from the four inch mulch as from no mulch at all.

3. The character of the rainfall.

Slight rains tend to cause shallow root-systems and are of no particular advantage in such a way destroying the effect of the soil mulch.

4. The character of the subsoil.

Just as important as the surface soil, an open subsoil, has a small water holding capacity and artificial applications should be made accordingly, great skill and good judgment must be used in application.

The frequency of forming a mulch is of as much importance as its depth.

6. Closeness of Planting.

An important factor affecting the duty of water when

expressed in terms of land served rather than in terms of crop produced.

7. Fertility of Land.

Using as a standard of comparison the unit area rather than the yield of crop, tends to make the duty appear less, due to larger evaporation which takes place from the more vigorous growth of vegetation, and the closer stand which the larger amount of available plant food renders possible. The real duty of water is, however, higher on the most fertile soil when based upon actual yield per acre.

8. Frequency of applying water. modifies the quantity which will be used during a season.

Frequent small applications are harmful in that they induce shallow root systems, increase the opportunity for evaporation, etc.

THE DUTY OF WATER IN RICE CULTURE.

The rice plant has an aquatic nature, making its water demands quite different from that of ordinary crops, and the amount required to bring a crop to maturity is considerably more.

The normal habitat of the plant is low, swampy lands, where the surface is more or less continuously under water. Occasionally threatened attacks by insect enemies make extra flooding necessary, and the water must not be allowed to become stagnant, which requires an enormous reserve of water for any sizable area of rice.

Various sources of data place the duty from one second foot for 25 to 66 acres; average 38.6, equivalent to covering the surface with water about 6-2 inches deep every ten days.

THE DUTY OF WATER ON WATER MEADOWS.

In¹ this form of irrigation immense quantities of water are used on the land.

In Italy the practice originated and has attained the highest stage or perfection.

The meadows are usually permanent, and have had their surfaces carefully prepared, so that the roots of the grass over the whole meadow are continually covered by a thin layer of warm water. This thin layer is kept flowing continually over the meadow through the entire year only being withheld long enough to cut the grass and remove it, to be fed to the cows green. By this method the grass is kept continually growing and as many as seven heavy crops have been taken off, giving a production of 45-50 tons per acre, and sometimes more.

The growing season is greatly prolonged, and it is found to be a cheap method of maintaining a high state of fertility of the soil, In some cases sewage waters are used.

If this water applied during the year was not drained off but allowed to pile up there would be three hundred or more feet, showing the enormous applications.

1. King, 219-220.

THE DUTY OF WATER IN CRANBERRY CULTURE.

This is another crop which thrives in swampy places where there is an abundance of water, flooding being used to protect the crop from insects, frost, and to prevent winter killing.

The surface of the ground water is seldom more than one or two feet below the surface, and the peaty soil is therefore continually saturated. There is no loss from such a bog by seepage, so that water is only necessary for flooding.

King 220-221.

Cold vs. warm water for plants.

It is the generally accepted opinion of florists and gardeners that watering plants with very cold water is detrimental to growth but no one has attempted to say how cold the water may be without producing this result. It is the common opinion, however, that water applied to greenhouse plants should not be much colder than the air surrounding the plants. The Wisconsin Station carried on some experiments with various plants and with various temperatures of water for various lengths of time.

From their results of the numerous trials, the conclusion appears fully warrantable that the growth of ordinary field and garden crop is not affected by the temperature of any water ordinarily available for irrigation purposes, and they conclude from their results that for outdoor work no harm can result from the using for irrigation purposes water from the coldest springs or wells, for the temperature of the water from these sources will not be less than 40 degrees in any case when taken from the well or spring, and by the means ordinarily employed this temperature will be somewhat raised before the water reaches the roots.

It is concluded from the results of the greenhouse work that for vegetables and flowering plants commonly grown under glass, well or spring water may be freely used at any time of the year without warming.

King.

From¹ an agricultural standpoint, the irrigating duty of water is that amount of water which when applied to a given area of cultivated soil will produce the best results.

In² clay soil the maximum yield of both wheat and straw was obtained by saturating the soil, approximately ten feet deep at each irrigation, or covering the ground with 26.82 inches of water during the season.

On caly soil containing more sand the yield of grain (wheat) increased as the water was increased up to forty inches, while the maximum yield of straw was produced with sixteen inches of water.

On clay soil containing little sand, timothy gave mixed results, although where the maximum amount of water 41.3 inches, was used the yield was greatest.

On clay soil containing more sand the first clover crop increased steadily and rapidly, from the use of 4.2 inches of water up to 9 inches. The application of 5.2 inches more of water decreased the crop nearly one half.

On poor gravelly, clay soil the greatest yield of grain (wheat) was obtained by irrigating every six days while the greatest yield of straw was produced by irrigating every twelve days.

All¹ plats receiving the same amount of water, during the season, there was very little difference in the total yield from plats irrigated every six, nine, twelve, or fifteen days respectively.

1. Utah Bul. 26. Fortier.
2. Utah Bul. 26, Sanborn.

Duty¹ of water under subirrigation, which means the application of water by some means below the surface of the soil.

Sub-irrigation is too costly for ordinary farm crops, the lateral motion of water is too slow to warrant sub-irrigation.

Soil watered in this way is warmer than surface irrigated, and the atmosphere around sub-irrigated plants is warmer to a height of twelve inches.

The sub-irrigated plat did not contain as much moisture as the surface irrigated plat at the end of the season.

2. METHODS OF APPLYING IRRIGATION WATER.

Methods of irrigation must vary according to the amount of water available, the soil, the lay of the land, the character of the crop, and there can be no best method to apply to all circumstances.

With the experience of half a century in California there have come to be a few methods generally recognized to be best, each for the conditions which govern its preference.

1. Distribution of moisture evenly throughout the soil mass to as great a depth as possible, providing it does not sink beyond the reach of the plant by root-extension nor beyond recovery by capillary rise.

2. Economy of labor both in aggregate time and in the feasibility of operating without employment of extra hands.

1. Utah Bul. 26, Sanborn.

3. Economy of water in the prevention of waste by overflow or evaporation or by rapid percolation, and in placing the water where it will do the most good.

4. Leaving the land in the best condition for attaining with least labor a state of tilth which conserves moisture, and at the same time favors thrift in the plant.

Cal. Bul. 53.

The¹ methods of irrigation in vogue are as varied as the topography of the country.

Practice and experience govern the amount of water to be applied to any given soil.

It has been found that practically a seventy per cent saturation of the soil will give the best results. Soil will take up seventy per cent of that water which it is capable of taking and still permit of good circulation of water and air so that plant growth is guaranteed.

A proper application of water is an even distribution over a well graded area, so that the entire surface will dry evenly and not in spots.

Application at the right time, in the right amount, without washing or puddling the soil or injuring the crop, requires an intimate acquaintance with the conditions; good judgment, close observation, skilful manipulation, and patience after the field has been put into excellent shape.

When water is applied to a soil which becomes more open in texture as the depth increases, the movement of any

water applied is straight down and in no case is the side movement very great. Where a fine, loamy soil is underlaid by three to five feet of subsoil with a finer texture through which water percolates slowly, water may be led quite rapidly through furrows some distance apart, giving heavy applications and depending upon a lateral spread, and capillarity to wet that soil between the furrows.

A very dry fine soil will take up water very slowly when flooded, since the surface pores become filled with water and this is held there with such a force that air from pores below cannot rise and give up their position to water.

Soil Puddling.

A soil is puddled when the compound particles are broken up into individuals and brought together again as one compound mass; when this takes place the water which is contained is held firmly until evaporation draws it out, and thus there is very little space for and very little soil air present. Plants die for the want of air; nitrification ceases, and the nitrates present in the soil may be denitrified. Water logging has the same effect as puddling.

It is practically impossible to flood with water a recently stirred soil without puddling it, so the best practice is to wet and then stir. When the seed are planted, or plants set, there should be enough water present in the soil to give them a good start, then when the plants have attained some size, the roots betting spread out, and the earth settling to its natural firmness, water may be applied in quan-

tity without as much danger of harm to the soil or plants.

Soil washing.

Caused by too large volumes of water hurried over the ground too fast.

Water in furrows will not wash if the slope is uniform so that the flow will be even and constant, and if the volume is kept not too great and not too small so that there is a constant flow the soil is not washed.

King.

Methods Used in Applying Water.

1. Free flooding, or running water without restraint except that afforded by the banks of the laterals conveying it.
2. Flooding in contour checks, or irregular-shaped inclosures which are determined in size and shape by the inequalities of the surface.
3. Flooding in rectangular checks, or inclosures which are approximately of equal size and with level bottoms.
4. Depressed beds, with raised ditches on the levees which hold the water until it soaks away among the inclosed plants--a garden modification of the rectangular-check-system.
5. Ridge irrigation, in which plants are grown on the sides or at the bases of raised ditches--a simple form of depressed-bed-irrigation.
6. Furrow plowing, or running water in one or more furrows between the rows of crops grown in that way.
7. Raised-bed-irrigation, in which the water is taken by seepage, and capillary action, from a small ditch on each

side--a modification of the furrow system.

8 Sub-irrigation, or distribution by means of pipes with suitable outlets, or from blind ditches filled with material permitting circulation of water which will reach the plant roots by capillary action.

9. Underflow irrigation, by which the ground-water is raised by percolation from ditches at intervals of considerable distance--the plant roots being reached directly or by capillary movement.

10. Distribution under pressure in underground or surface pipes, with stand pipes and connections for sprinkling.

11. Skinner irrigation, a spray system.

Farmers' Bul. 138, pp. 26-27.

CONSIDERATIONS IN CHOICE OF SYSTEM OR METHOD.

Slope of the land.

Character of the crop.

Character of the soil.

Labor requirement.

Ease of cultivation after irrigation.

The time when water should be applied depends upon the nature of the crop, the soil and the weather.

Farmers' Bul. 131.

Flooding.

A method¹ proving very satisfactory on land where the natural slope is good as at Union Colony, Greeley, Colorado, where fields of 40, 80, and even 180 acres are flooded. A main supply ditch is run along on the side with highest elevation, then shallow plough furrows are made from this,

to guide the water, canvas dams are used in the ditch to throw the water out, water is allowed to run through to far end of ditch, then dams used along at the necessary distances toward the supply ditch to warrant all the land being flooded. It is impossible to get an even distribution, as any low places will be over watered while the ridges will be hardly moistened; it is rather a deceptive method of watering although it is cheap and rapid.

Flooding definite areas at a time by means of checks is probably the most satisfactory way to flood. Its advantages are:

1. It is possible to know that a certain amount of water has been applied to the inclosed or flooded space.
2. Enables the irrigator to quickly spread a considerable depth of water over the surface and bring even moisture.
3. It facilitates the use of a large run of water in a short time.
4. Gives satisfactory irrigation where other methods fail.

Free flooding is where streams are allowed to overflow their banks and the land being level the water forms a constant layer over the surface and soaking in. Only feasible to use where the land is level or has a very constant and gentle incline.

Flooding in contour checks: where portions having the same level are flooded at one time, being held in place by ridges thrown up around the edges of the piece.

Flooding in rectangular checks as where a field is laid out in rectangles by laying up furrows, water let into these rectangles, to insure even distribution on slightly rough land, when one rectangle has been well soaked water turned out turned out into next and so on.

From New Jersey Bul. 115, 1895.

Water brought in a three inch main from the city reservoir, one thousand feet away, from this main lateral pipes lead off to the various plots, these laterals end in uprights which are provided with faucets above ground, furnishing centers for irrigation by means of surface pipes and garden hose. Capacity with inch pipe and hose with the slight fall from the reservoir is nine gallons per minute.

Utah Bul. 39. Mills.

In experiments with different systems an average of six inches at each irrigation proved best.

Five methods of distributing were tried on grass land; a network of small ditches gave the best results. Those methods which distribute the most evenly give the best yield.

Flooding increased the yield of wheat 23% over farrow.

Utah Bul. 80.

With a given amount of water, better yields of corn were obtained from flooding than from furrow system.

Nevada Bul. 52.

In Nevada the low lands are irrigated by damming the river as it overflows its banks. Flood and check also used.

In¹ the Rocky Mountain states the gravity system is naturally used.

In² Wyoming the ranchmen turn the water on the meadows, as early as possible in spring, and allow it to flow up until cutting time to wash off the alkali, to withdraw the frost in spring, to start growth early, and keep growth constant.

In³ Connecticut, where the supply is obtained from springs, ponds and streams, being pumped by rams and windmills, the greatest economy is used in distribution, pipes laid along one side of the field, water run between rows, sprayed, and open ditches.

Basins⁴ are used largely in orchards. They tend to keep the roots near the surface, and they saturate the soil, making it liable to cake and bake. It also causes quite a disturbance of the soil to make an individual basin around each tree.

Furrow irrigation seems to be the better method for orchards and cultivated crops. The loss from evaporation is small, it permits the use of smaller streams of water to better advantage than any other method, but it is not the most rapid method.

The most common method in arid regions is to flood

1. Office of Expt. Stas. Bul. 73. (Ulrich)
2. " " " " 81. (Buffam).
3. " " " " 36. (Phelps).
4. " " " " 158, pp. 51-52.

from small field ditches; for grain and grass, it is a cheap method, does not disturb the soil, does not interfere with the use of machinery, but it is rather difficult to control.

The check method is best adapted to light, sandy soils having a comparatively even slope of from three to fifteen feet to the mile, a large volume of water can be used cheaply, the high cost coming in the preparation of the land.

IV. 3. RELATIVE IMPORTANCE OF LARGE AND SMALL APPLICATIONS OF WATER.

From¹ the standpoint of labor, the fewer the number of irrigations, the less is the labor and thus the cost.

From the standpoint of the duty of water, the less often the surface of the soil is wet, the smaller will be the loss by evaporation and by seepage in bringing the water to the fields.

The amount of water to be applied at one time is as much as the crop will tolerate without suffering in yield or quality, and practice the most thorough tillage to keep this water after it is applied.

The soil regulates to some extent the amount of water which may be applied at any single irrigation, the type of plants whether shallow or deep rooted will also come into the consideration. A heavy application applied to a light soil with a loose subsoil and a low water-table for a shallow rooted crop will likely insure loss from seepage.

In Arizona with deciduous fruit trees experiments proved that winter irrigation was most satisfactory. But if water was abundant in summer, it would probably be wise to give the orchard a thorough irrigation in as short a time as possible, following with a thorough ploughing to protect against evaporation.

Frequent summer irrigation is decidedly not advisable where the soil is fairly deep and retentive of moisture. In winter there is more rain and flowing water, and it should be saved, the showers of late summer should be saved by following with cultivation.

The value of thorough irrigation was proved by the tracing of roots of peach trees to a depth of twenty feet.

Deep winter irrigation followed by thorough summer cultivation is the best for deciduous orchards in Southern Arizona, much better than frequent applications of small amounts of water during the growing season.

Arizona Bul. 37.

1. Utah Bul. 29 (J. W. Sanborn).

Best¹ yield of grain was secured where water was applied sufficiently to saturate the soil 1 1/2 feet.

Best yield of grass was secured from the heaviest application of water 2 1/2 feet.

Soils reserve most of the soils from water applied beyond soil saturation.

Water escaping from soils by leaching is richer in

the elements of fertility than before it entered the soil; the amount which so escapes is so small in comparison with that applied, that it contains only a fraction of the solids applied.

2. Utah Bul. 80.

On shallow bench lands.

Heavy irrigations increase the per cent weight of heads of plants; light irrigations increase the per cent of leaves.

In the seeds of corn, wheat, and oats, the fat and nitrogen free extracts are increased by free applications of water; in the corn kernel the per cent protein increases as the amount of irrigation decreases. Increased irrigation increased the starch content and decreased the protein of the potato. Increased irrigation increased proportion of ear to stover in corn, grain to straw in wheat, and per cent marketable potatoes. Best yield of potatoes came from frequent small irrigations.

Yield¹ of crop and texture of soil are the main factors in governing the applications of water to the soil.

If a crop of corn yields seventy bushels to the acre it may be brought to maturity in 110 days with 11.75 acre-inches of water.

A soil of medium texture may carry in its surface four feet 4.5 inches of available water and if extremely open 2.5 inches. In such cases three irrigations would be

1. King, 234.

necessary on the medium soil and five on the open intervals between waterings 37 and 22 days respectively. If the yield was increased to 100 bushels, irrigations necessary would be 4 and 7 with intervals of 27 and 15 days.

Same way with wheat with 40 bushel yield, 40 bushels requiring 12 acre-inches three or five irrigations, intervals. 33 or 20 days.

Barley 60 bu hels per acre in 88 days requires 12.84 acre-inches, 3 or 5 irrigations at 29 or 18 days.

These three examples are of the highest limits likely to be attained under best field conditions, and may serve as a standard to work toward since they are actual examples.

In all parts of the world the average number of irrigations for wheat are from three to five, when supplemented more or less with natural rainfall.

Allowing 110 days as the requirement for maturity of corn

In Egypt the crop requires	7	waterings every	15	days
" New Mex."	"	"	6	"
" Italy	"	"	3	"

In Italy the rainfall is quite large and nearly sufficient to mature a crop. Thus it would seem and it has been shown by experimental study that where the corn crop has to depend upon irrigation for the water needed, that applications must be made at intervals of 15 to 27 days for yields of 100 bushels per acre.

IV. 4. IMPORTANCE OF MULCHING IN RELATION TO IRRIGATION.

Mulching¹ is nothing more than another kind of irrigation in a milder form. Mulch retains moisture during dry times. In 1894 mulched strawberries withstood a drought while others died. Mulched with little irrigation gave better results than not mulched and irrigated and requires more water. The results which may be obtained by mulching depend very largely upon the season.

2. When² the damp surface of a soil is covered with a dry mulch, evaporation is very greatly decreased as has been shown both in field and laboratory experiments.

The most effective soil mulch has been shown to be the one of the coarsest texture and the deepest. For instance, a three inch mulch of coarse sand is better than a three inch mulch of fine clay loam, and a three inch mulch of coarse sand is better than a two inch mulch of the same material.

Any mulch will deteriorate with age, as it settles and reverts to its original condition, even though it has no rainfall on it, showing that a mulch should be frequently reformed.

Although the greatest means of protection against evaporation is the soil mulch there are many other forms of mulch. All forms of vegetation growing upon the soil serve more or less as a mulch, by shading the soil, by reducing the velocity of the wind close to the surface, and by transpiration from the leaves, saturating the air with moisture which

1. New Hampshire Bul. 34. F. W. Rane.
2. King.

would otherwise be taken up by evaporation from the soil.

Manure mulches also prove very beneficial, especially coarse strawy manure, adding plant food and conserving moisture. The surface dressing of grass meadows with farm-yard manure has proved very beneficial.

The¹ loss of water from soils takes place practically altogether from the surface of the soil, Evaporation has, therefore, a very close dependence upon capillarity. The evaporation of a little water from the surface inch of a soil decreases the water content of that inch, the capillary pressure increases correspondingly and water is drawn from lower and moister layers to restore the equilibrium. Continued evaporation must, then, be accompanied by a continued capillary supply.

Thus it is obvious that evaporation will be shut off if the capillary supply is interrupted and this is the secret of the so called "dry mulch" which consists of a layer of dry material of any sort, even dry soil, spread over the surface to constitute an interruption to the continuity of the capillary films, breaking the pipes or ways through which the water has been coming to the surface, and preventing its further rise.

IV. 5. RELATION OF IRRIGATION TO ALKALI.

Alkali² soils occur naturally in arid lands and they may also be the result of irrigation; in humid regions by natural drainage the undesirable salts are carried away while in arid lands water is carried away by evaporation and the salts are left behind accumulating at or near the surface of the soil.

1. Plant World, Vol. 14, 8-Mar., 1911.
2. King.

Alkali is commonly made up of salts of sodium, magnesium, calcium, sometimes potassium, mostly as carbonates, chlorides, and sulfates. Carbonate of sodium, the so called "black alkali," is the most dreaded, and white alkali includes all the other kinds of salts.

The¹ presence of one-twentieth of one per cent of sodium carbonate in the soil will often injure a crop, while one-tenth of one per cent of the dry weight of the soil will prevent the germination or kill the seedlings of most of the common crop plants.

All soils may contain a certain amount of alkali salts but it is the question of their distribution through the soil, and the amount in the upper two or three feet, which is important.

When water is applied to a soil containing soluble salts, first it is drawn down by the two forces, gravity and capillarity. Gravity being the greater force and pulling the larger portion down through the larger openings between the soil particles, such as holes made by worms, roots, etc., this first flush of water dissolves the surrounding salts, and by capillarity, acting in the finer pores, this first water which has taken up the quickly dissolvable salts is largely taken up and held in the capillary spaces. Thus the greater part of the salts are held in these spaces and the last part of the water passes down the gravity tubes practically pure. When the supply stops at the surface and evaporation starts again, water is drawn upward by capillarity to

replace that lost by evaporation, so that water containing the greater portion of the salts is pulled up and the salts are deposited as evaporation goes on. A second application is made and the same process repeated, the alkali salts increasing at the surface rather than decreasing, showing that in order to correct alkali some means of drainage is necessary in connection with irrigation.

Irrigation alone is a means of increasing alkali, while irrigation and drainage are a means of the correction of alkali.

Irrigation applied to a field containing a large per cent of alkali salts and of higher elevation than surrounding fields will, if applied too heavy, dissolve the salts of the high field, seep down to the lower area, bring the water-table up near the surface and make a heavy deposit, causing the low field to become unproductive of crops.

Methods employed in reclaiming alkali lands are:

1. Chemical correction, adding something which will change the salts chemically into a compound either insoluble or inert, as adding gypsum to soil containing sodium carbonate.
2. Growing resistant plants.

There are plants which can grow in the presence of more alkali than other, such as sorghum, kaffir corn, and sugar beets, but the amount of alkali is more apt to increase than to decrease so that these crops will fail to grow after a time and some method of reducing the alkali has to be resorted to.

3. Cultivation and mulching.

Lessening evaporation decreases the formation of alkali at the surface.

4. Removal of alkali.

The salts may be scraped up and carted off the surface, but the source still remains and a new layer will soon be found.

Flushing water over the surface has the same effect, so some method must be used to get at those salts which are down deeper than the surface layer.

5. Underdrainage and leaching.

Allow the water to carry the salts down and out.

Alkali¹ salts are formed by rock deterioration. They collect in the soil because the rainfall is not sufficient to carry or wash them out.

Salt bush, a pasture plant in Australia, and kano in Africa, are plants which will survive a high per cent of alkalinity.

Alkali injures plants at the root crown, really girdling at the point where the plant stem leaves the soil, since the water in its upward movement brings the salts up in solution and evaporation allows a surface deposit to be made.

Black alkali is the worst form, and is carbonate of soda or salsoda; It has a puddling effect on the soil besides its effect on plant growth.

Gypsum has a correcting effect on black alkali.

IV. 5. A DANGER FROM EXCESSIVE IRRIGATION AND THE REMEDY.

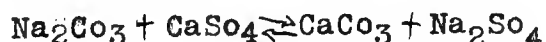
It has frequently been found in the irrigated regions, that soils which showed but very little alkali when first brought under cultivation have after the lapse of a comparatively few years become so widely impregnated with alkali as to make them unfit for growing crops. Before irrigation was introduced the salts were present in rather large amounts, but well distributed through the soil, and not in such large quantities in any one place as to be injurious to plant growth. With the introduction of irrigation, however, water was applied in excessive amounts to the higher lands, and seeping through to the lower soils carried with it the soluble salts, which accumulated in excessive amounts in the latter, especially where drainage was imperfect. This water removed the valuable salts from the higher land and brought them together in such quantities in the lower land as to ruin plant life there and also by taking the salts away it decreased the fertility and thus the plant life on the higher land.

So even if proper drainage systems were used to carry off this water with its salts it would be harmful as the salts in small well distributed quantities are valuable, and any washed away by excessive watering is wasteful or plant food.

In the¹ majority of cases even with a porous sandy subsoil, underdrainage will hasten the reclamation of alkali land to such an extent that the rapid reclamation will pay for the installation of the system, lines of drain tile being advised for the system of underdrainage.

Calcium sulfate has a correcting effect upon black alkali.

Black alkali is sodium carbonate and when the two substances come together a chemical action takes place expressed by the following formula:



When the calcium sulphate is added to the soil, it is adding more of the alkaline material, but in its action upon the sodium carbonate it reduces the injurious effect on plant growth, so that plants will grow on a soil which is in reality

more alkaline than it was before.

If¹ the soil is not well drained, the reverse reaction will predominate and may be indicated as follows:



When gypsum comes in contact with chlorids in solution or in a wet soil, calcium chlorid and sodium sulphate will be formed.



1. Field operation of Division of Soils, 1899, pp. 54-55.

IV.

(6). Relation of irrigation to dry farming.

Usually in discussing dry-farming conditions the annual precipitation is the only feature of the rainfall that receives attention, but there are other features or factors in connection with the rainfall that have much to do with the successful production of crops.

The seasonal distribution of the rain, the rate at which the rain falls, and the amount of rain that is lost through run-off from the surface all have an important part in the determining of the percentage of the total rainfall that is really available for the use of the crops. Prospective settlers in regions of limited rainfall are apt to give very little attention to the climatic features other than the total rainfall, which may be for one single year rather than the normal yearly rainfall, they ignore almost completely the seasonal distribution of the rain, the frequency of torrential rains, the loss of water through surface run-off, the occurrence of hail, and the amount of evaporation.

The U. S. Weather Bureau have published some valuable figures which they have collected at their stations in these regions, and which should be very valuable to prospective settlers.

Dry farming regions are naturally classified on the basis of rainfall. In this country dry-farming is usually considered to be confined to those regions in which the annual rainfall is less than 20 and more than 10 inches.

Dry-farming methods are usually understood to mean those which lead to the conservation of moisture, but the conception of what these methods actually are varies greatly in different sections of the country. The dry-farmer in the Great Plains usually gets his best results with annual cropping methods combined with good tillage with 15 to 20 inches.

On the other hand the dry farmers in that part of the Great Basin where the rainfall is less than 15 inches follow the method of alternate cropping and summer tillage almost exclusively.

Between these two classes there is a third operating under conditions where summer tillage may be necessary to insure returns on every crop, but where it frequently pays to take chances on producing a crop on the land each year.

The method of alternate cropping and summer tillage is generally recognized as the most highly developed dry-farming method because it gives better returns with a lower annual rainfall than other methods, especially in regions of winter rainfall, like central Utah.

While the method of alternate cropping and summer fallowing is recognized as the most highly developed dry-farming method, it does not follow that it is the best method for all dry-farming regions or that it will always give the best returns.

The-United-States The rainfall in all parts of the United States is subject to wide fluctuations from year to year, and it is very important to farmers that they know the normal annual rainfall in their section, crops in the East are often lost through drought and not infrequently under conditions that the up to date dry-farmer would have produced a crop.

The¹ combination of special tools, special methods of cultivation, and drought resistant crops as means of overcoming drought has been given the name dry-farming.

The semi-arid regions between the line of 20° and the Rocky Mountains presents one of the greatest problems to American agriculture. Between 1883 and 1889 many settlements were made in this region, due to successful crops being raised during three wet years. The appearance of two or three dry years caused abandonment. There is no lack of fertility, and the difficult problems are in the direction of heat and moisture. Rainfall is scanty and irregular; the scorching winds which change green fields of corn into dry and rattling stalks in twenty-four hours are the difficulties.

Summer following one year and growing a crop the next has proved successful but it is not sure, so irrigation bears an important relation, as the dry farm needs enough irrigation to provide a living for the tenants in dry years and to insure some green object all the time.

This irrigation can be provided by pumping from soil water or underground streams. Storage in surface reservoirs of stormwaters and the irregular flows of the streams, irrigation with flood water in winter and spring.

Dry farming is practiced in the semi-arid regions where there is a fair rainfall during the winter months but almost none in the growing months, so that irrigation has to be used in supplement to rainfall and in connection with the methods used in dry farming.

IV.

7. SEWAGE IRRIGATION.

The use of the discharge from sewers; waste water.

Irrigation furnishes a very good means of disposal for various waste products, making them of use rather than sources of annoyance. In most places the sewage is run into streams when it is finally destroyed by sunlight and exposure to the air. Many cases have been noted, however, where sewage was dumped into one end of a stream and drinking water taken from the other end, causing great danger to public health.

Many elaborate experiments have been carried on to demonstrate the practicability of using sewage in the irrigation of farming land. Where the practice is carried on the chief difficulty arises when the sewage must be applied winter and summer, making it necessary to provide large areas of land and to apply the sewage water more with the idea of getting rid of it than of the actual need of the plants.

Soils of a loose sandy nature are capable of handling extremely large quantities of sewage waters, as the water percolates through and leaves the organic matter at the surface where plant roots can get it. If a sewage farm is properly handled, there need to be annoyance from it. Applications followed by cultivation place the organic matter in a position where the soil bacteria can work on it and soon put it in the form of available plant food.

Sewage irrigation has proved itself profitable even in humid climates where there was sufficient rainfall to carry the crop through, the value of the sewage water being its fertilizer value. If it proves of value under such conditions there surely should be none wasted in the arid and semi-arid West.

This method of disposing of sewage may be called a form of slow intermittent filtration in which the top of the filter is used to grow plants.

There has always been the question raised as to the liability of disease being carried on the plants from such practice, especially on those crops which are eaten uncooked.

and
Tests, analysis have been made and every case has proved that the practice is a perfectly safe one.

The methods of applying the water are similar to those employed in the use of ditch water, flooding and furrow being used followed by cultivation.

Sewage irrigation is a problem from the point of view of sanitation.

The composition of sewage water depends upon the conditions and is variable.

Average analysis of four samples are as follows:--

Water	97.4%	Nitrogen	.45%	Potash	.2%
Ash	1.1	Phos. acid.	2		

Sewage irrigation is especially good on light sandy soils, where the large amount of water is valuable as well as its fertilizer content, the crops most suitable for growth on

land thus irrigated are those crops which are cooked before eating, although all investigations and tests have proven no disease to be caused in this way.

"The¹ meadows near Edinburg (England), once arid and worthless, have, by being flooded with the sewage of the city, risen to an enormous value, and are annually let by public auction at prices varying from 15 to 32 pounds per acre. An estimate of the green fodder cut annually from each acre is from fifty to eighty tons."

Chemical analysis of sewage waters showed them to be rich in ammonia, soluble alkaline salts, phosphates,

1. Morton, Cyclopedia of Agr., p. 823.

V. COST OF IRRIGATION.

1. Water.

2. Distribution.

The¹ average cost of pumping water found at the well plants in Louisiana and Arkansas was:

In Louisiana with an average lift of twenty feet, cost \$6.67 per acre.

In Arkansas lift forty feet, cost \$11.61 per acre, to irrigate.

On² six hundred and forty acres in New Jersey 32 plots each containing 20 acres, water pumped from a stream and distributed by pipes at a cost of \$45,000, about \$70.00 per acre.

6600 gallons of water pumped hourly by windmills and stored in tanks of 66,000 gallons capacity, ~~ten~~ acres of land to a square with a well in the center instilled at a cost of \$4500, or \$45 per acre, to be irrigated from it. A substitute gasoline vapor engine for the windmills, of a capacity to deliver 6600 gallons hourly doing away with the tanks cost \$3500; engine of capacity of 3300 gallons hourly reduced price to \$2500, using three inch pipe in place of four.

Small³ irrigation plants in New Jersey cost from \$190 to \$600.

Gasoline engine and windmills for one acre \$190. Steam pump for five acres \$600, an

1/	Office	Expt.	Stas.	Bul.	201.
2.	"	"	"	"	36.
"	"	"	"	"	87.

Pumping¹ the average for the summer, of an acre-inch of water, lifted thirty-five feet required:2714 gallons gasoline at .12 1/2¢ costing .33 9/10¢ per acre-inch.

Fitting the ground 24¢ per acre, distributing water, 14¢ per acre.

Average rate of pumping 540 gallons per minute, or 1.2 cubic feet per second.

Cost² of check irrigating in California. Estimate of cost to check and prepare twenty acres for irrigation, \$361.00 or \$18.08 per acre.

Cost to check and seed 160 acres, \$1593.04 in three-quarter acre checks, of \$9.96 per acre.

A³ well sunk at the New Mexico Station at a cost of \$150, with a 20 H. P. engine could irrigate land three inches deep at a maximum cost of from 51 to 64 cents per acre with short runs.

Engine to pump 1000 gallons per minute from a well two hundred feet deep cost \$10.00 per acre.

Artesian Wells.

Flowing wells, the deeper the well the warmer the water and the richer in minerals.

In⁴ Colorado the wells of a two inch bore, producing from five to twenty-five gallons of water per minute, cost from twenty-five to seventy-five dollars.

1. Off. Expt. Stas. Bul. 133, pp. 266.
2. " " " " 145, " 84.
3. New Mexico Bul. 45.
4. Colorado Bul. 16

The Conrad Bucher well sunk in Colorado in 1889 gets a flow of six hundred gallons per minute from a depth of 932 feet, and cost \$2700 largely for the casings, water exceeds one cubic foot per second.

At¹ New Jersey a belt containing 1/120 of an acre was used to grow beans and this belt was used as a basis for computing larger areas.

Price of water one dollar per thousand cubic feet.

Water applied at the rate of 27,032 cubic feet per acre making a cost per acre of \$27.13.

Increased the yield per acre sixty bushels of number one beans at a cost of forty-five cents a bushel.

7.48 Cu. ft. = 1 gal. water. 27,032 Cu. ft. = 202,200 gals.

Cost² of Pumping as shown in the Santa Clara valley of California varies according to the power used, size of the pump and the depth of wells.

In 1900 cost of pumping with cost of fuel estimated.

Number 4 pump centrifugal, operated by gasoline engine, water taken from a well 70 feet deep cost \$3.00 per day. Resulting in the pumping of 600 gallons per minute, 36,000 gallons per hour, or 360,000 gallons in a day of ten hours. Calculated to irrigate about four acres with two inches of water.

- 1/ New Jersey Bul. 115.
2. Farmers. Bul. 116.

B. IRRIGATION OF TRUCK CROPS IN HUMID SECTIONS.

I. Extent of irrigation in the Eastern United States.

I. General Farming.

This type of farming is carried on under conditions where land is relatively cheap and abundant, the soils are light loam and during years of fairly constant rainfall the crops are satisfactory. Field crops are not generally irrigated although all experiments which have been carried on have strongly shown the value of irrigation.

King at the Wisconsin Experiment Station carried on experiments of irrigating general field crops, and obtained an increase in the yield of clover hay of $2\frac{1}{2}$ tons per acre, with corn the increase was 26.95 bushels per acre, with potatoes 83.9 bushels increase. By comparing the yields with the general yields of the state and deducting the cost of irrigating, the result was in net profit per acre, \$20.00, \$11.00, and \$14.00 respectively on the three crops. This would seem to show that where water can be readily obtained, irrigation will pay on the general field crops.

In Pennsylvania hay meadows are irrigated to some extent, especially near the beds of small creeks which are fed by springs; the increase in yield of hay is from 50 to 75 percent.

In nearly all the humid sections of the Eastern States there are frequent droughts during the growing season, and generally they come at the critical time, as when the corn ears are filling, and when the potatoes are forming, thus greatly decreasing the yield of crop, if water could be applied at this time it is perfectly safe to say the yields could be doubled.

The droughts always seem to come during the months of May and August, when the crops are starting and when they are maturing, and at the times when the greatest possible damage can be done.

In these sections the water comes from wells and ponds very largely, pumps or windmills are used to raise the water and take it to the field, where it is distributed either in furrows for the row crops or by spraying for the small crops, and these systems of application are expensive.

The grower of special crops can see advantages enough to afford the expense but the general farmer who is not dependent upon any one crop for his living is not likely to invest too heavily, if his potato crop is nearly a failure because of a drought he still gets enough for his own use, and a successful crop of something else will overshadow his loss, if his corn fails to fill good ears he uses the stalks to feed his cattle and thus does not feel any direct loss as does the special crop grower who is dependant on that crop. The result is the general farmer goes on from year to year expecting better success the next time if he fails once, never considering what he might do by investing in an irrigation system.

2. Special Crops.

While the general farmer may make up with one good crop what he looses on another, the grower of a special crop is dependent upon the success of that crop, and he will do anything within his power to make that crop do its very best. If it is a Cranberry bog it must be flooded and kept moist, if it is a rice field it must be treated practically the same.

In general it might be said that a ~~man~~ growing a special crop will see anything which will be of benefit to his crop much quicker than will the general farmer, and if it be irrigation that his crop requires he will spare no effort to establish a system, with the expectation that it will repay him by increased crop production.

3. Fruits.

The Small-Fruits as a rule do not require especially large quantities of water and in the humid states there is always water enough present in the soil to bring the crop through/ the blossoming stage, the time of greatest importance however is the time of setting and maturing the fruit and a deficiency of water at this time means a crop of small, seedy and inferior fruit. In a season of sufficient rainfall there is therefore no direct benefit from an irrigation system, at least there will be little benefit, but when a drought does occur the benefits are great enough to pay for the installation of such a system.

With the tree fruits there is always a large amount of evaporation from the large leaf surface and consequently large amounts of water are taken from the soil. At fruiting time if the supply is deficient the fruit will be small, misshapen, and poor in quality.

Thus the man who can irrigate when his crop is receiving a check by drought has a normal crop and receives a high market price while his fellow competitor who cannot irrigate has either a poor crop or none at all. In fact it might be made a general statement with any crop grown, that the man who can grow a good crop by means of irrigation and proper conservation of moisture, reaps a rich harvest while the unfortunate one is a loser.

4. Vegetables.

Throughout the humid regions irrigation is practiced where vegetables are grown. Vegetable or truck gardens are always on high priced land in close proximity to cities where large crops must be grown in order that the land may return a profit to the grower. Very few of our vegetable growers keep records of the cost of and profit derived from irrigation, but they all agree that it is of great value. In ordinary years it increases the yield, and in dry years it means a full crop in the place of no crop, the returns in a single dry season often equal the first cost of providing the water-supply.

II. Systems of obtaining and distributing water.

Where irrigation is only practiced on a small scale the supply generally comes from the city waterworks, and is applied to the fields by some spray system.

In the humid sections there is very little water which can be applied directly from gravity streams, there are however some places as in Pennsylvania where hay meadows are flooded by damming the streams which flow through it and in this way flood the meadow, but this is only possible in a few places.

The general water supply is from springs, ponds, wells, driven-wells and streams. The water is taken from these by different systems of pumping as windmills, rams, and steam and gasoline engines, and is carried through pipes to elevated tanks or reservoirs, or under pressure directly by pipes to the fields where it is distributed.

As to methods of application the greater part is sprayed, while some is run in furrows and some flooded.

Water is all carried to the fields and distributed through galvanized pipes (iron), usually two inch pipes are used.

III. Methods of applying water.

In humid regions the sprinkling system prevails over all others, due to the fact that the quantity of water applied at one irrigation has to be relatively small in comparison with the amounts used in the west, since the risk of a sudden thunder shower which may over soak the soil has to be considered.

The advantages of the sprinkling system is that there is no loss of space if the main pipes are laid underground, and there is no loss from leakage; it is applicable to uneven ground and hillsides, with no special preparation of the surface required since the water

is applied under pressure and as a fine spray, the only disadvantages are the first cost for piping and pump.

The furrow system is cheap and simple and proves quite satisfactory with row crops on heavy soils, its special advantage is that it may be applied at any time since the water does not come in contact with the foliage. There is a loss of space where the head laterals are used, and there is expense for piping where it is used in the place of the head laterals, it also costs to make the furrows and to cultivate them in.

One method quite largely used is hose sprinkling, main pipes are used to carry the water to the field where they are divided into smaller pipes or laterals which are sunk under ground at regular intervals and have frequent surface openings with hose connections. This is an expensive spray method from the standpoint of labor, and is in most cases soon substituted by a mechanical spray system of some kind.

There are several spray systems in use of which the Skinner is the more general at present.

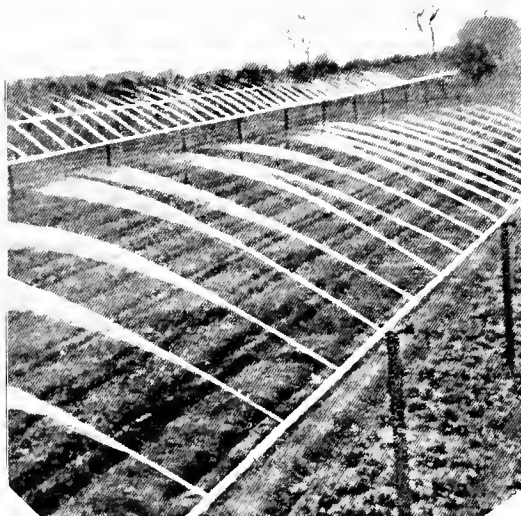
Beside the Skinner system there are the Keeley system, water-witches and multiple sprinklers. all of which require water under pressure to operate.

THE SKINNER SYSTEM.

The Skinner System is essentially an overhead spray system, it consists of parallel lines of pipe, in which are inserted specially devised nozzles, located in the pipe at distances approximately four feet apart. The nozzle lines are from 40-60 feet apart, depending upon the local conditions. The water is distributed in a manner which insures absolute uniformity; which covers every square inch of soil whether it be smooth or rough, and it is under the control of the operator.

The Skinner Union is placed at the head or entrance of each sprinkling line of pipe, and acts as a filter, furnishing additional protection to the nozzles, also permitting the ready rotation of the pipe. The size of the pipe and the pressure available governs the width which one line may be expected to cover.

SKINNER SYSTEM-



As it is used out o' doors.



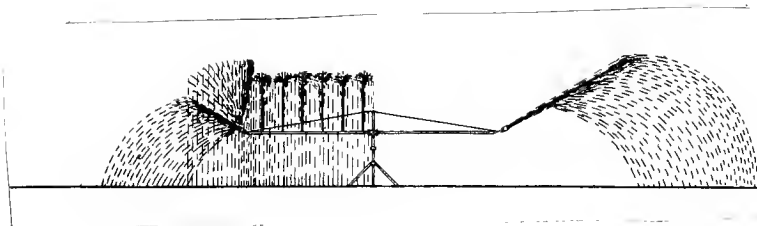
As it is used in the Greenhouse.

KEELY SYSTEM.

This system is an enlarged multiple sprinkler or water witch it requires about one minute per revolution, and applies water evenly. A system costs from \$50. to \$100. All pipes are laid under ground with connections for these eprinklers at the surface.

WATER WITCHES AND MULTIPLE SPRINKLERS-

These are modifications of large whirling spray nozzles, and are used in various sizes from the small ones used on lawns to the large ones mounted on small wheels and moved across a field, as shown in Baileys Cyclopedia of Agriculture Vol. I, p 439.



Keely Sprinkler.

IV. Amount of water used per application and season.

Arnold Schmid & Son of Nashville, Tennessee, used 2,000,000 gallons of water on three acres of heavy loam soil for truck crops during the growing season of 1910.

H. F. Chester at Cleveland, Ohio, applied on a very light sandy soil 60,00 cu. ft. of water per acre in 1910.

C. F. Venable, Florida, applies one gallon per square foot of surface twice a week in hot weather. (1910).

The type of soil is one of the main factors which controls the application of water, a light and sandy soil requires much more water for the successful production of crops than does a heavy loam soil which is retentive to moisture.

As to the amount of water to be used at each application, it is coming to ^{be} realized that the best practice is to make heavy applications at intervals, and follow with shallow cultivation, rather than make frequent shallow waterings.

Some growers say make applications heavy enough to meet the ground water, others say wet the soil down four to six inches and still others apply from 1/2 to 1 inch of water at each application.

There can be no general statement made to cover every region and every condition in the country, on this most important question of how much water to use per application and season. Every grower should know his soil, know his climate and know the water requirements of his crops; when he considers these he can apply water to an advantage and get the best results.

The time of application of water.

When applied in furrows it may be done at any time. When

sprayed on the foliage there is less loss by evaporation and less damage done to the leaves if applied in early morning and late afternoon.

V. Cost of applying water to different crops and soils by different methods.

The¹ cost of irrigation is greater in the East than in the West for several reasons.

1. More piping is used in the East.

2. Because of the pipe distributing systems the cost for power plants and fuel is larger in the East.

3. Elevated tanks and spray systems require greater lifting power than is required to deliver water on the level.

Where pumping systems are used there are certain fixed charges which must be taken into consideration whether the plant is idle or in use, such as depreciation, repairs and interest on investment.

With steam power plants the average total cost to deliver the water ready for distribution on the land is given as \$28.00 per acre foot.

City water is quite uniform in cost, the average given is \$1.11 per 1000 cu. ft., \$48.00 per acre foot or \$16.00 per acre for an application of four inches.

The cost to irrigate an acre of land one season in Eastern States is from \$30 to \$100.1.

Cost² to apply 17550 gallons of water is \$2.35.

H. M. Howard, Mass. says, "City water costs 30¢ per 1000 gallons and when my pump is running full speed it costs me 2 1/2 ¢ per 1000 gallons to pump."

1. Office Expt. Stas. Bul. 167.
2. New Jersey Bul. 115.

Wyman Bros., Mass.

Cost $2\frac{1}{2}\%$ per 1000 gals. to pump water rom a well.

R. E. Roork, N. J.

Cost to apply one inch of water to an acre of soil, exclusive of labor 40¢.

Arnold Schmid & Sons., Tenn.

City water costs 8¢ per 1000 gallons.

G. H. Heft, Penn.

Gravity springs supply water at a cost of 25¢ per 15000 gals.

C. F. Vinal, Florida.

Cost \$2.00 per day of ten hours to run a plant which has a capacity of 690 gallons per minute.

VI. Crop returns from irrigation.

1/130 A.

Experiments at the New Jersey Station. Plots 11 X 33 feet¹

Golden Wax beans were planted as a second crop from August 24 to Sept. 17, from Sept., 17 to Oct. 5, ten applications of water were made between the rows, 150 gallons being applied each time, the total amount equalling an application of eight inches, or at the rate of 202,200 gallons per acre.

The nine non-irrigated plots gave a yield of 17 lbs. 1 oz., *36 lbs* nine irrigated yielded 45 pounds. *95 lbs per A.* The irrigated plots therefore produced nearly three times as many by weight of large sized pods, *at 150 gal. per A. prod. 88* having better color and quality than the non-irrigated. *water 10*

✓ Pepper plots of the same size, given applications totalling 1830 gallons from august 24 to Oct. 4, increased the yield from 80 pounds of poor pepers on non-irrigated to 147 pounds of good peppers on the irrigated. *Net 38*

Celery, one tenth acre field of average loam soil, with grav-elly loam sub-soil, one half of which was irrigated and one half not irrigated. The cost of the irrigation was \$1.14 for 8,531 gal-lons applied.

The irrigated portion yielded 329.5 pounds of celery while the non-irrigated gave 136 pounds. In the marketable product the ratio was three to one in favor of irrigating celery, while the selling price was eight to one in favor of irrigation.

Increase due to irrigation.

	Gallons applied	Cost.	Amount applied per plant.	Percent Increase.
Beans	1685	\$.225	5 gals.	164%
Peppers	1830	.244	22 "	83%
Celery	8513	1.138	13.5 "	142%

Irrigation of strawberries in Conn.²

Two irrigated plots gave a yield of 337 quarts.

Two non-irrigated plots gave yield of 132 quarts.

The yield figured per acre for the irrigated plots would be 5318 quarts, and for the non-irrigated plots 2,083 quarts.

The berries from the non-irrigated plots sold at nine cents a quart while those from the irrigated brought eleven cents a quart, making the selling price per acre for irrigated berries \$584.76 and for non-irrigated berries \$187.46. Showing a balance in favor of irrigating strawberries in Connecticut of \$397.30 per acre.

George W. Heft of Hellertown, Penn., says, "the increase in my vegetable crop due to irrigation on dry seasons is as follows in percent:"

Lettuce	85%
Celery	70%
Spinach	60%
Radish	40%
Lima Beans	40%
Strawberries	45%
Beets	50%

D. C. Smith of Florida says, "during the five years I have irrigated fruit and truck, my crops have been increased 75% three years and 50% the other two.

M. E. Moore of Arlington, Mass., says, "I use the Skinner system of irrigation both in the Greenhouses and out-of-doors and know that the increase in crop value produced by the ability to irrigate pays for the installation of the system every year."

Chas F. Leabrook of New Jersey says, "My crops are increased one half by irrigation."

F. Schumacher of Long Island says," In dry years the ability to irrigate is worth surely \$1000 on 15 acres of truck crops."

The¹ average yearly value of truck crops in nine cases is given as \$1030 per acre of which value the irrigators claim \$330 is due to irrigation, or an increase of 47%. Estimates run from 30 to 50 percent increase, with a safe profit of \$200 per acre due to irrigation.

1. Office Expt. Sta. Bul. 167, p. 49.

VII. Sewage Irrigation. Extent of practice, crops.

Sewage irrigation is a practice which is still to be developed; where it is used it gives satisfaction, and when we stop to consider the vast amount of fertility which is lost through waste of sewage, and think of the increase there might be in crop production by its proper application to the soil, we can easily see its value.

The value of sewage water has been proven on the hay meadows of England, and in America it has been used somewhat on truck crops with complete success.

VIII. Outlook of irrigation under humid climate. Kinds of soil and crops to which best applicable and their probable extent.

¹Irrigation of hay meadows and truck farms is an established and profitable practice, but the value of irrigation to general farming is still to be demonstrated.

At the present time irrigation is carried on very successfully on the loam soils of the truck crop sections, it has proved a paying proposition on light soils especially where vegetable crops were grown.

There is no doubt that farm crops could be easily doubled by the use of irrigation at times of drought and with the spray systems now out of the experimental stage, I look for a great increase of area under irrigation in the humid sections, especially on the light loam soils, and where the value of the crop grown is sufficient to warrant the investment for an irrigation system.

1. O. E. S. Bul. 167, Conclusions.

New York.

Frederick Schumacher, Flushing, L. I.

Irrigated truck crops, fifteen acres, for fifteen years, on a sandy loam soil. Water is supplied by driven wells, being pumped by windmill and four H. P. gasolene engine into tanks holding 13,000 gallons and directly into pipes supplying the Skinner lines.

Crops on this light soil require water at certain times during each year, and at these times thorough irrigations are given.

Beleive the cool portion of the day the better time to apply water but find it necessary to run all day during the severely dry spells; in dry years the ability to irrigate is surely worth \$1000.

Philip Bach, Flushing, L. I.

Twenty acres of truck irrigated twelve years on a sandy loam soil with the spray system. Water is taken from driven wells by a steam pump with a capacity of 100 gallons per minute, pumped into a large tank and carried from here by underground pipes to the field where it is applied by pipes with Skinner nozzles; irrigating thorough and following with surface cultivation.

John G. Schumacher, Flushing, N. Y.

Skinner system used on truck crops, water applied in the afternoon when possible.

D. Titus, Irondequoit, N. Y.

Twenty one acres of truck crops irrigated two years on a sandy loam soil. The water is pumped from a pond by a Gould Triplex pump with a capacity of 21000 gals. per hour. This water is carried to the

field under a pressure of 80 pounds in 6 inch pipe as a main, and applied by the Skinner system.

Massachusetts.

H. M. Howard, West Newton, Mass.

Irrigated seven acres of truck crops three years with Skinner system.

Soil medium loam, fine sand subsoil, water supplied by 8 H. P. Foos Gasolene Engine and Deming triplex pump from wells, furnished in the pipes at 80 pounds pressure. City water also used.

Apply water from 4 P. M. to 6 A. M., making thorough applications and following with shallow cultivation.

"I know I can advance the maturity, improve the quality and increase the quantity of salable produce, but as for comparative figures, I have kept no check. I crop the land heavy and apply water when I want to try to grow something without waiting for rain. Crops nearing maturity can be matured and the land put in condition for the next crop by a thorough application of water."

City water costs 30¢ per 1000 gallons. Can pump that amount for 2½¢.

Wyman Bros., 129 Lake St., Arlington, Mass.

Irrigated 30 to 75 acres of truck crops for 25 years. Soil sandy loam, rather fine sub-soil, some heavier meadow land underlaid with clay. Water pumped from a well close to a lake by a 25 horse power gasolene engine and Triplex pump, (considering substitution a 25 H. P. Electric motor for the engine). Cost to pump 2½¢ per thousand gallons.

Some fields fitted for Skinner others piped for hose irrigation, the water is pumped to a stand-pipe and lead to the fields through a six inch main, where it is divided to supply laterals two and three inch.

Crops like cabbage grown in rows are furrow irrigated.

Such crops as onions, carrots, beets and spinach are irrigated by using a coarse hose spray; the surface pipes are so arranged that not more than 150 ft. of hose is required to reach from one connection to the next.

Spraying is done in evening while furrow irrigation is done at any time during the day.

Thorough irrigation, deep enough to meet the moisture beneath followed by surface tillage.

Irrigation often means the success or failure of our crop, and we raise twice as much produce per acre now as 25 years ago.

M. Ernest Moore, 278 Broadway, Arlington, Mass.

Irrigated twelve acres of truck crops for fifteen years on a variation of soil from a light and sandy to a heavy clay soil. It would be impossible to secure first class crops every year without irrigation, and there is a time every season when water is necessary. Supply is pumped from wells (driven), by means of a Deane duplex steam pump, throwing 80 to 90 gallons per minute, through iron pipes to the field. Method of application favors the Skinner system and it is used entirely.

Water is applied in sufficient quantity to thoroughly wet the ground and as soon as the surface has dried sufficiently shallow

cultivation is begun. "I do not consider it practical in this section to try to raise truck crops without a good system of irrigation. I consider Skinner system the best and cheapest method of applying water and know that I can apply an immense amount of water at a very small cost. Used it out of doors and in greenhouse five or six years, and it pays for itself every year; covers a large area in the very best manner."

Wilfred Wheeler, Concord, Mass.

Irrigated two to three acres of strawberries for pot grown plants for eight years; using the Skinner system and find I could not grow the crop without irrigation and this system has cut labor bills one half. Water is carried through 1 1/2 inch and 1 inch pipes and applied at a pressure of 38 pounds, from six to eight P. M.

Applications are thorough and followed when the surface dries by shallow surface cultivation.

H. F. Hall, Brighton, Mass.

Irrigated 4 - 10 acres of truck crops five years on a black sandy loam soil with a sandy sub-soil.

The water supply comes from a well and the city; steam pump gives a pressure of 60-100 pounds in the two inch main and 1 1/4 inch laterals in the field. Applied with a hose by flooding, wetting down from 4-6 inches. When spraying water on the foliage it is done from 4 P. M. to 8 A. M. in furrows and flooding at any time.

Follow irrigation with shallow cultivation; we find it necessary to use water when planting or transplanting from June 25th to Aug. 1st.

New Jersey.

R. Elwood Roork, Greenwich, N. J.

Three acres of truck irrigated two years on a light loam soil by the Skinner system. Water supplied by pumping from driven wells with a $3\frac{1}{2}$ H. P. gasolene engine and a Gould pump with a 48 gallon per minute capacity. Water carried under 20 pounds pressure to the nozzles, applications made of from $1\frac{1}{2}$ to 1 inch at each time, stirring the soil surface as soon as it can be worked.

Cost to apply the water, about 40 cents to apply one inch of water to an acre of soil exclusive of labor.

David Astle, R. F. S. #6, Vineland, N. J.

Seven acres of general crops irrigated on a variation of soils, water is pumped from artesian wells from 16-35 feet deep, by a Myers pump and 5 H. P. Gasolene Engine, capacity 35 gallons per minute. Pumped to a tank on a hill from which pipes lead to the field where connections are made with a spray system mounted on wheels, the nozzles used are called water witches. For a description and illustration see Cyc. of Agr. (Bailey) Vol. I, p. 439.

We could not grow celery at all without irrigation and we have doubled and trebled the yield of other crops by its use.

Geo. A. Mitchell, Vineland, N. J.

Has proved the value of irrigation on truck crops and small fruits.

An experiment with the irrigation of various crops is given in O. E. Stations Bul. 87. pp. 26-33.

Chas F. Seabrook, Bridgeton, N. J.

From one to fourty acres of truck crops irrigated eight years on heavy and light loam soils. Water is pumped by Fairbanks and Moore Duplex pump and 8 H. P. Gasolene engine from a well and a creek directly to the Skinner system pipes at from 30 - 40 pounds pressure. Applications are made heavy and followed by surface irrigation. Crops increased 1/2 by irrigation.

Fred W. Kilbourn, New Brunswick, N. J.

About four acres of truck crops irrigated thirteen years on a heavy loam soil. City water is used and is applied in furrows at the rate of 5000 cu. ft. per acre per year. After applying water the furrows are filled in to prevent evaporation.

C. Becker, Vineland, N. J.

One half acre of strawberries and vigitables irrigated five years on a sandy loam soil. A Gould force pump furnishes the water from artesian well, and it is applied to the land through revolving water witches after sundown.

Tennessee.

Arnold Schmid & Son., 1010 Caruthers ave., Nashville.

Three acres of truck irrigated by Skinner system six years. City water is used at 60 pounds pressure, and sprayed on, 2,000,000 gallons being used per season on a heavy loam soil. Very little cultivation is given any more than to keep down the weeds and grass. Water costs eight cents per thousand gallons, and sometimes means the saving of the entire crops.

Georgia.

J. C. Wheeler, Albany, Ga.

"I regard the Skinner system superior to any other for irrigating truck crops.

I have irrigated six acres of oranges on a sandy loam soil and some seasons double my crop by its use.

Water is pumped from wells by means of Gasolene Engine and centrifugal pump of capacity of 15000 gallons per hour, distributed through furrows 4-12 inches deep and 10-16 feet apart, the amount applied varying with the dryness of the season. Application followed by light surface cultivation.

Cost depends upon proximity of water supply, kind of power used and method of distributing water".

Ohio.

M. L. Rueterick, Brooklyn Sta., Cleveland.

Five acres of truck more especially celery irrigated eight year on a sandy loam soil with clay and gravel sub-soil. Water supplied from a pond by a standard pump of 7000 gallons capacity per hour. Furnished water at 50 pounds pressure to the Skinner system. Water applied evenings, from 1/2 inch to 1 inch applied each time. Some seasons a great benefit others no particular benefit.

H. F. Chester, Cleveland, Brooklyn Sta., R. F. D. #2.

Seven acres of truck irrigated eight years by the Skinner system on a medium loam soil. Three acres is sandy gravel four feet deep, four acres is sandy loam with clay sub-soil.

Water comes from reservoirs filled by wet weater brooks and from city mains; water carried to field in two inch pipe under a pressure of 50 to 60 pounds. Very heavy applications made since the soil is very light and requires it, 3,000,000 cu. ft. applied per five acres.

Celery mulched with manure as well as other crops which can be, others cultivated as soon as possible after each application of water. In Cleveland it would be time thrown away to attempt to do intensive vegetable gardening without irrigating facilities.

Pennsylvania.

R. H. Garrahan, Kingston.

Eight to twelve acres of truck crops irrigated 25 years on a sandy loam and clay soil with clay sub-soil.

Water supplied by Knowls pump (steam) 100 gallons per minute on 80 pounds pressure at Skinner nozzles; from a pond and creek.

Methods of applying water are by flooding and the Skinner system, being followed by surface cultivation. Cost and amount applied unknown.

George W. Heft, Hellertown, Pa., R. F. D. #1.

Six acres of small fruit and truck irrigated with water witch sprinklers on a sandy loam soil.

Water furnished by gravity from springs furnishing 10 gallons per minute and giving 25 pounds pressure at the witches.

Applications of 150 gallons are made to circles 25 feet in diameter.

Water cost estimated at 25¢ for 15000 gallons, which is a days flow from the springs. In dry season the increase in crop due to irrigation in per cent is as follows: Lettuce 85, Celery 70, Spinach 60, Radish 40, Lima Beans 40, Strawberries 45, Beets 50.

Florida.

D. C. Smith, Center Hill.

Twelve acres of fruit and truck irrigated five years on a sandy soil with a light sand and clay sub-soil.

Water supplied from a well by centrifugal pump and 15 H. P. gasoline engine, supplying 400 gallons per minute to the Skinner system, which applies one inch of water to the surface in seven hours.

After the plant is installed, it costs about \$3.00 per days watering.

The Skinner system is the best for truck farming.

During the five years practice the crops have been increased 75 percent three years and 50 percent the other two.

C. F. Venable, Center Hill, Fla.

Four acres of truck crops irrigated four years with the Skinner system on a dark loam soil.

Water supplied by pumping with an International Gasolene Engine 15 H. P. and a No. 1924 Gould pump from wells driven from 45 to 90 feet deep. There is always an ample supply of water and it is delivered at the nozzles under a pressure of 48 pounds.

Try to apply one gallon per square foot of surface twice a week in hot weather, and follow with shallow cultivation. Crops that close their blossoms at night are watered at night, others anytime. Irrigation proves a very profitable proposition. It costs \$2.00 per ten hours to run this plant which has a capacity of 690 gallons per minute.

IMPORTANT POINTS BROUGHT OUT BY CIRCULAR LETTERS-

state.	Grower.	Crops Irrigated.	Acres Grown.	Years Irrigated.	Soil.	Source Of Water.	How Applied.
Mass.	H.M.Howard.	Truck.	7.	3.	Light-heavy Loam.	Well & City.	Skinner System.
"	Wyman, Bros.	"	30-75.	25.	Black sandy Loam.	Well.	" & Hose.
"	M.E. Moore.	"	12.	15.	Medium Loam	"	Skinner.
"	W. Wheeler	Strawberries	2-3.	8.	Light Loam.	City.	"
"	H.F.Hall.	Truck.	4-10	5.	Black Sandy Loam.	Well & City.	Flooding with Hose.
Ohio.	H.F. Chester	"	7.	8.	Sandy Loam.	City.	Skinner.
"	M.L. Ruetenik	"	5.	8.	" "	Pond.	"
Georgia.	J.C.Wheeler.	Orange Grove.	6.	-	" "	Wells.	Furrow.
Florida.	D.C.Smith.	Fruit & Truck	12.	5.	" "	"	Skinner.
"	C.F.Vinable.	Truck.	4.	4.	Heavy Loam.	"	"
Tennessee	A.Schmid & Son	"	3.	6.	Med-heavy	City.	"
N.Jersey	C.Becker.	"	1/2	5.	Sandy Loam.	Wells.	Water witches.
"	F.W.Kilbourne	"	4.	13.	Heavy Loam.	City.	Furrow.
"	C.F.Seabrook.	"	1-40	8.	" " & Light "	Wells & Creek.	Skinner.
"	G.A.Mitchell.	"	-	-	" "	"	--
"	David Astle.	" & General Cr	2-7.	-	Med Loam.	Wells.	Water witches.
"	R.E.Roork.	Truck.	3.	2.	Light Loam.	"	Skinner.
N. York.	J.G.Schumacher	"	-	-	-	-	"
"	Philip Bach.	"	20.	12.	Sandy Loam.	Wells.	Flooding with Hose.
"	F.Schumacher.	"	15.	15.	" "	"	Skinner.
"	D. Titus.	"	21.	2.	" "	Pond.	"
Pennsylvania.	G.W.Heft.	Fruit & Truck	5.	6.	" "	Spring.	Water witches.
"	R.H.Garrahan.	Truck.	12.	25.	" " & Clay "	Pond & Creek.	Skinner.

Applying. Gained by		Int of	Cost.	Tillage
Water.	Irrigation	Water Applied		Practice.
		At each Time.		
Howard.	4PM-6AM.	Advance maturity, About one Improve quality, Inch. & Quantity	City, 30 cents per Thousand cu ft. Cultivation 2 1/2 cents to pump it.	Stuffle hoeing, and Shallow Cultivation.
Wyman.	" "	Increase the yield to double.	Thorough when needed.	" " "
Moore.	" "	Diff. some seasons	Thorough.	Skinner system Stir the surfa
	All day	between no crop and a good one.		pays for itself ce after it
Wheeler.	6-8 PM.	Could not grow the crop without.	\$.30 per M. Gals.	is partly dry. Stir with fine tooth cult.
Hall.	4PM-8AM.	It always pays.	Wet down 4-6 inches depending on the soil condition.	Stir surface as soon as dry enough to work.
Chester.	6-9 AM. 4-10 PM.	Could not grow crops without it.	Very heavy applications.	Mulching and shallow stirring.
Ruetenik.		Some years a benefit others not.	1 1/2-1 inch.	-----
Wheeler.		Depends on rain.	43560-gals per acre semiweekly.	----- Light surface. cultivation.
Smith.	After 3PM.	Increase for 5 yrs. first 3, 75% 2, 50%	One inch.	\$3.00 per day Surface after to run the it dries is plant. stirred.
Vinable.	"	A very profitable practice.	43560 gals per acre semiweekly.	\$2.00 to run Followed by ten hours and shallow pump 690 gals cultivation.
Schmid.	Any time	Some years entire crop saved.	2000000 gals a season	8 cents per Very little thousand gals. only to kill weeds.
Becker.	Afternoon	Very beneficial on strawberries.	half hour every evening	--- ----
Kilbourne.	Night.	Some years the full value of the crop.	5000 cu ft per acre per year.	Thorough.
Seabrook.	Any time	On light soils, Benefits crop	1 1/2 1/4-Inch each application and 4-10 inches for whole season.	" "
Mitchell.			1 1/2-1 1/2 Inches per application.	
Astle.	Any time	Double & Treble.	one inch per app.	Shallow.
Roork.	Morning & Afternoon.	Difference betw- een a failure and a good crop.	1 1/2-1 Inch acre inch exclu sive of labor.	"40 cents per As soon as surface has dried, shallow.
Schumacher	"			
Rach	"	Great advantage on a dry season.	Good soaking	Shallow.
Schumacher.	"	Worth \$1000. dry years.	" "	"
Titus.	"	Could not do without.	" "	---
Reft.	"	40-85% increase.	150 gals on 25 ft circle. days flow from	15000 gals. "" springs.
Arrahan.	Anytime	A great benefit.	Dont know.	Shallow.

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